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Monthly
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The Progress of Science

The Inventor of Canning: Appert's Bicentenary

It is ironical to realise how little popular acclaim the inventor of the familiar canning process that has affected the larders of the world has received for his inventiveness. He was Nicholas Appert (1752–1841).

Appert was the pioneer of canning, though the first containers he used were not cans at all, but glass bottles! He invented the process of 'sealing the seasons', a contemporary term given to the preservation of all types of foods in jars and in cans by the combination of sterilising and subsequent sealing.

Even in technical literature one finds inadequate reference to this modest Frenchman who anticipated Pasteur's work on 'pasteurisation', as the latter so readily acknowledged. ("When I published the first results of my experiments on the possible conservation of wine by preliminary heating, it was evident that I only made a new application of the method of Appert, but I was absolutely ignorant that Appert had devised this same application a long time before me," wrote Pasteur in his classic *Études sur le Vin.*)

Pasteur's name is immortalised far beyond the confines of the world of science in the term 'pasteurisation'. He introduced this technique of sterilisation by heat first to the wine industry. Soon afterwards he applied the same method to milk, but here it was that Appert had anticipated him. A dairyman of Gournay had consulted Appert about the difficulty of keeping milk fresh, and Appert told him to bottle it and to heat the bottles by means of very hot, or even boiling, water for a short time. The dairyman took his advice, with most successful results; he found that milk so treated could be sent on a two-day journey to Rouen without deteriorating in transit.

Appert's bicentenary calls for world-wide celebrations on a grand scale; a revolution in food preservation was set in train by his painstaking efforts, and the result has been the creation of a vast industry which cans some ten million tons of food a year. 'Painstaking' is the right word to apply to Appert, for his genius epitomised Edison's definition of that quality—"One per cent inspiration, ninety-nine per cent perspiration". Unlike Pasteur, Appert had no scientific training, indeed his schooling was practically nil. Yet his countless experiments bore the stamp of a true scientist; he was not merely an acute and accurate observer, but also a man who extracted hypotheses from the data he devised by observation and experimentation, and who tested those hypotheses against the results of further well-designed experiments. His achievements were the more remarkable because they preceded by so many years the establishing of the science of bacteriology.

The son of a wool-comber of Chalons-sur-Marne, Appert gained wide practical experience through working in wine cellars, kitchens and grocers' storehouses. He was both a jack-of-all-trades and master of every trade he was associated with; he was fully entitled to style himself a "brewer, pickler, distiller and confectioner", for he was an expert in all four trades. His practical experience of handling foodstuffs made him appreciate to the full the difficulty of preventing perishable foods from going bad. The ubiquitous saprophytic moulds and bacteria which attack Man at his most vulnerable point—his food supplies—constitute a mighty army which is every bit as difficult to contend with as that other vast army of micro-organisms, the parasites and pathogens which continually hold the threat of direct physical invasion over Man's body. Around 1795 Appert opened a new chapter in the history of food preservation, and he did so in spite of the fact that science could offer him little assistance in the way of facts or theories relevant to the mechanism of putrefaction. Existing methods of food preservation were essentially primitive methods upon which Man had relied for generations. Desiccation, for instance, had long been widely used; countless centuries before A. P. Herbert's pet abomination—the word 'dehydration'—insinuated its way into the food industry's vocabulary, primitive man had discovered that strips of meat which had been dried in the sun kept well, and for a long time, if stored in a cool place such as a cave. Some primitive tribes met the problem of putrefaction in a quite different way; assuming this problem to be incapable of solution, they relied on fresh milk from their domesticated animals—more rarely they relied on fresh *blood*, as the Masai tribe of Africa continued to do right into the

twentieth century—except when the time came to kill an animal, the carcase then being disposed of in one gargantuan orgy which entirely eliminated the problem of putrefaction that inevitably arose whenever they attempted to keep back some of the meat and store it for another day. This kind of custom may seem very thriftless to the people of temperate regions, but it is, of course, sound practice in tropical regions where the high temperature makes putrefaction a much more rapid process.

Salting, smoking and pickling are all very ancient methods of preserving food. The use of salt as a preservative, for example, can be traced back two or perhaps three thousand years in Egypt; brining of vegetables as practised today is at least as old as the nomadic Tartar civilisation which, under Genghis Khan, controlled an empire stretching from the Pacific to the river Dnieper. (The extraordinary mobility of the Tartar cavalry owed much to the way it solved its problems of food supply.) Salted meat and fish were staples of the winter diet in the Middle Ages; the salt-cured herring, for example, was 'invented' in Europe in 1283. Smoking is presumably an older system of food preservation than salting; for when primitive man started cooking his food over a fire, he set the scene for the prehistoric discovery of the good keeping properties of smoked food, an accidental discovery which was probably made dozens of times by keen-witted savages quite independently and in many different countries.

Pickling has a link with salting, and the first pickled meat that can be traced in the records goes back to the mid-thirteenth century, when Pokling cured both beef and bacon in a solution of salt and saltpetre. Pickling with vinegar may well date back far beyond recorded history; certainly vinegar and nearly all its modern uses were familiar to the Egyptians, and as vinegar is the product of a natural fermentation process there can be no doubt that many men had handled its prior to the Egyptians, and its preservative property must have been swiftly noticed. (Almost certainly the preservative property of strong alcohol was discovered even earlier; the practice of pickling fruits in alcohol must be very ancient indeed.)

This brief review of the food preservation methods available before 1795—one ought to include refrigeration, which the Eskimos and others had used for centuries—will enable the reader to appreciate the limited range of foods which could be stored and eaten without risk of food-poisoning during the winter season. The demand for new preservative techniques was strong enough in all conscience, for the need for them was so obvious. Yet when Britain's Royal Society of Arts offered a prize to any one who could find a better method of food preservation than salting, the offer was made in vain. In 1782 Scheele, the pioneer Swedish chemist, came within an ace of devising an efficient technique of sterilising food by means of heat; much of the vinegar of those days went bad rapidly, and Scheele demonstrated how its keeping properties could be improved by heating it, bottling it, and then keeping the air away from the 'pasteurised' vinegar by covering it with a layer of light oil. Scheele's experiment established the principle that it is essential to exclude air from the material after it has been sterilised by heat. Scheele was, however, far too interested in more erudite and intricate problems of a purely chemical nature to develop his idea to its logical conclusion and apply it to the preservation of perishable foodstuffs.

The next advance—the crucial step which took Scheele's idea right into the realm of food sterilisation on a factory scale—did not come for another twelve years or so. France was at war with the whole of Europe, and her army and navy needed large supplies of meat and vegetables. As new battle-fronts were opened and her military supply lines lengthened, it became imperative for France to find a way of processing meat and vegetables so they would keep fresh and nutritious during transport over hundreds of miles, and during storage lasting many months in supply depots. The French Government offered 12,000 francs to the man who could invent such a process. The winner was Appert, the "brewer, pickler, distiller and confectioner", whose achievement gained high praise from the judges—Gay-Lussac, Guyton-Morveau and Parmentier.

The containers in which Appert sterilised the food, afterwards sealing them to exclude air, were bottles. The sterilisation was effected with an autoclave. (This machine was a development of Papin's digester, which was originally designed for a quite different purpose, but which was as much the precursor of the autoclave as it was the ancestor of the modern domestic pressure-cooker.)

The full details of Appert's process can be studied in his classic book *Livre des tous les Ménages, ou L'Art de Conserver, pendant plusieurs années, toutes les substances animals et végétales*, published in 1810, and now generally known in Britain by the abbreviated title *The Art of Preserving all kinds of Animal and Vegetable substances.*

In it he describes the special wide-necked bottles he used, and how he sterilised and sealed them. The bottles were corked after sterilisation, and the seal was made as near perfect as possible by dipping the neck of the bottle in melted wax, the wax drying to form an airtight barrier between the food in the bottle and the air outside it. Typical of the way Appert gave his attention to the smallest details is his instruction that the cork stoppers must be cut to ensure that all the pores run horizontally across the cork; none of the pores must run downwards through the cork, otherwise after the stoppered neck of the bottle has been dipped in the wax air might still be sucked into the bottle as it cools. Every bottle was given six hours in the autoclave.

By 1804 there existed many testimonials to the efficacy of Appert's process. As, for example, that of the Marine Prefect at Brest, who stated that after a three-months' journey by road all the Appert-ised provisions were in sound condition; the broth, he reported, was good, the beef very edible, and the vegetables had the flavour of fresh ones.

Long after his classic book was acclaimed in editions abroad, Appert continued to work in his factory, which he visited almost up to the year of his death. The House of Appert supplied preserved fish, eggs, game and milk, which kept just as well as his preserved meat, vegetables and broth. He used to work the factory's autoclaves himself, when his assistants were terrified by the not infrequent accidents which occurred with the primitive autoclaves of his time. On one occasion he delivered 17 kilos of beef sealed in a single container, this time made of metal instead of glass. (As a memento, a member of the House of

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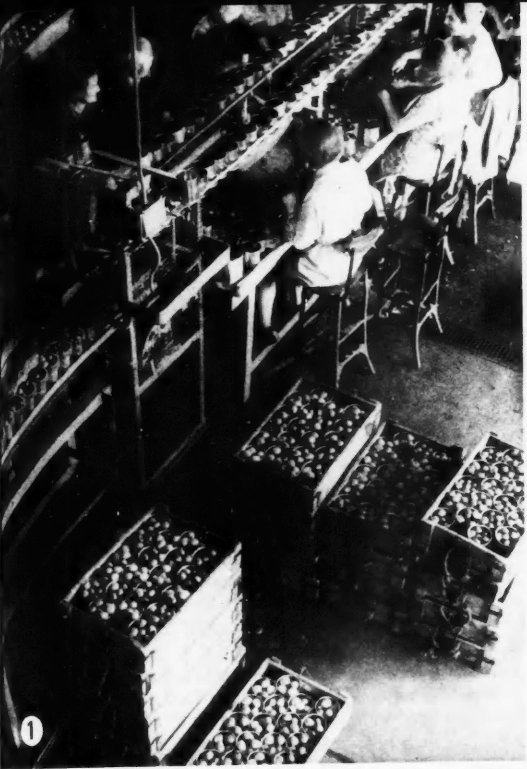
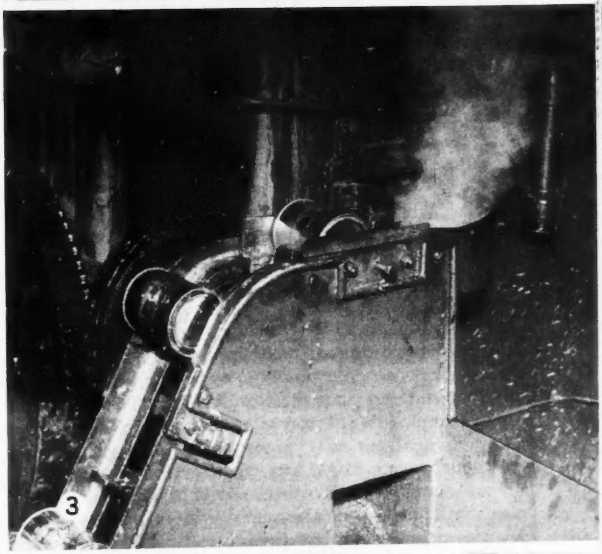
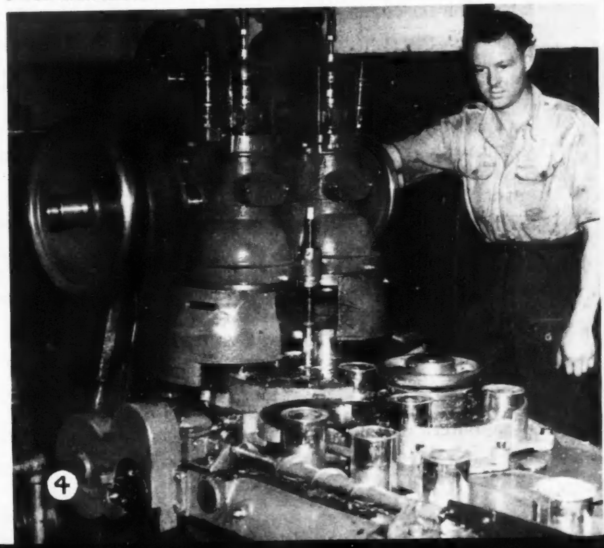






SEQUENCE OF TYPICAL CANNING PROCESS

1. The cans are filled.
2. The lids are loosely clinched on by this machine.
3. The cans go through the exhauster machine which removes the air.
4. The seaming machine makes the cans airtight.
5. The sealed cans are sterilised in autoclaves.

(*Pictures 2–5 by courtesy of Smedley's Ltd.*)

Appert showed in an exhibition in 1852 a whole sheep cooked and sealed in a huge can four months previously.)

It was the Napoleonic wars which established the reliability of Appert's process beyond a shadow of doubt. Within a few months of its adoption by the French authorities, bottles of Appert-ised food fell into the hands of British soldiers, and were brought back to this country for examination. The upshot was that a factory, bottling food by Appert-process, was started at Bermondsey as early as 1812.

The beginning of the canning industry, as we have seen, depended on the use of glass bottles! Glass was not a suitable material for the purpose, and Appert's own experiments with metal containers indicate that he was fully aware of the snags inevitable with glass at the stage when the bottles were heated in the autoclaves. Metal containers would obviously stand up to heating better than glass, but most metals remaining in prolonged contact with food are corroded, and the compounds resulting from such chemical action spoil the flavour or appearance of the food even if they are not downright poisonous. In Britain attention soon concentrated on the possibilities of canning in tinplate containers, which were first tested and then manufactured in England by Bryan Donkin and John Hall, founder of Dartford Iron Works.

The early cans were so solidly made that "opening them was more of a job for a safe-breaker than a housewife"; indeed, some of them carried the instruction: "Cut round top with a hammer and chisel." The design of satisfactory tin cans was a most important development, for it opened up the prospect of mechanising canning factories to a much greater extent than could be possible so long as the process had to rely on fragile glass containers. A great many technical problems had to be solved before cheap tin cans could be mass-produced, and the British contribution in this connexion was outstanding; before the pioneers of the canning industry placed their orders for large numbers of tin cans, the cladding of iron with tin was scarcely more than a metallurgical curiosity of no commercial significance. The metallurgists found the challenge presented by the canners' demand for tinplate as stimulating technically and scientifically as it was commercially. It is a fact that they can now produce, by hot-dipping and rolling, tinplate in which the tin coating is no thicker than 0·00008 in. (By electrodeposition it is possible to save over half that tin, the thinner coatings—0·00003–5 in. thick—having come into favour recently as a result of the world tin shortage.)

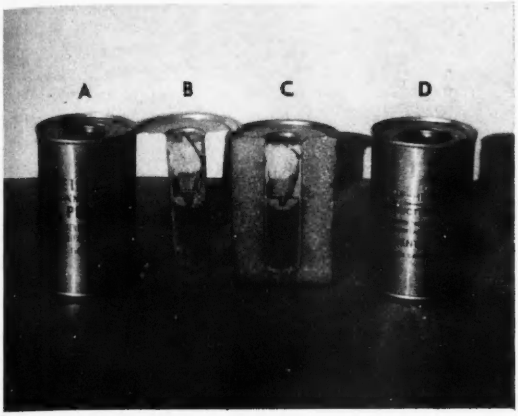
In 1840 preserved foods in Appert-type bottles were very expensive, and the bulk of the earliest 'canned' products found their way into military supply depots. They quickly found favour with soldiers and sailors, being far more appetising than the customary ingredients of the military rations which were adequate in calorie-content but in no other respect.

Once cans had been substituted for the glass containers such foods were adopted by explorers. As early as 1824, we find Parry including tinned foods such as beef and pea soup in the stores of H.M.S. *Fury* in which he sailed to the Arctic.*

* Some of that batch of tinned food was opened in 1937, and it proved to be still in good edible condition! Viable bacterial spores were present in the tins, which means they had survived in a state of suspended animation for over a hundred years.

The development of the meat-producing countries of S. America owed much to the invention of canning. Originally these countries supplied Europe with wool, bones and hides; meat was only a by-product, and nearly all of it was thrown away. Liebig, the great German chemist who specialised in the application of chemical knowledge to agricultural problems, invented the technique of reducing meat to a concentrated extract similar to Bovril, and this process was introduced to S. America in 1865, a factory financed with British capital being set up at Fray Bentos in Uruguay. Liebig's method of meat preservation absorbed some of the waste flesh, but not until canning factories and refrigerated ships became available was it possible for S. America to develop its meat-packing industry, and so take its place as a major meat-supplier to the rest of the world.

Canning has come a very long way since Appert's day, and science has done much to improve the industrial techniques used so that the original taste, texture, colour and composition of the foods are affected as little as possible in the process of canning. The plant breeder, too, has contributed his share, developing new varieties of fruits and vegetables which take more kindly to cans than did the old ones. Some of the latest ideas which scientists connected with canning factories are testing, are described in the chapter on food-processing which Mr. Bacharach and Dr. Crosbie-Walsh contributed to the new O.U.P. book, *Four Thousand Million Mouths* (1951, price 12*s*. 6*d*.). The sterilisation of such heat-sensitive foods as meat is still far from perfect, and is immediately obvious from the fact that no one, not even a blindfolded person, can fail to distinguish the familiar corned beef out of a can from natural meat. The vast difference between the two is due to the drastic heat-treatment necessary to sterilise the tinned meat. Modification of the process is called for, and this problem challenges the ingenuity of scientists and technologists. Germicidal gases might be pumped into the tins in order to render the contents sterile; they would, of course, need to be flushed out before sealing the packs. Perhaps silver or copper could be introduced into the plating of the cans, for minute traces of such metals prevent bacterial growth. Another suggestion which is being tested is that certain packs could be preserved by very short periods of heating if the antibiotic called *subtilin* were added. (This antibiotic, of bacterial origin, is entirely non-toxic to man when eaten.) 'Flash pasteurisation' of milk damages the composition and flavour less than the old-fashioned method of pasteurisation; perhaps a similar method—the principle of which would be sterilisation at a higher temperature but for a shorter time (a matter of minutes, even seconds)—could be used with meat. The biggest difficulty is to bring the whole of the contents of the can to a high enough temperature in a very short time; dielectric heating appears to be one possible method here. Sterilisation by means of bombardment with energetic electrons has also been tried experimentally. There is clearly plenty to occupy the attention of scientists and technologists working in close collaboration on the problems of the industry which Appert launched on its fantastic career. Celebration of his bicentenary in technical circles will be most valuable if it stimulates research and development in this industry which has had so profound an effect on the way of subsistence of the whole world in peace and war.



SELF-HEATING FOOD CANS

Self-heating food cans are used by the British Services (*right*), the heating cartridge being lit with a burning cigarette.

(*Above*) *A* and *D* represent the opposite sides of a can of soup fitted with a heater cartridge. *B* is a section through the heater assembly contained in the centre of the can, showing the heater cartridge with the special igniter passing through the anti-smoke filter. *C* is a section through a filled can of soup fitted with a heater cartridge assembly. The heater cartridge is contained in the steel tube which is fixed to the lid of the can and is held centrally in the liquid soup. Only the heat is transmitted through this steel tube to warm the soup.

(*Courtesy, I.C.I. Ltd.*)

M.I. Science

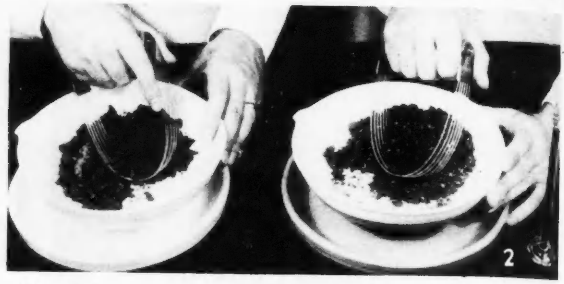
It is announced that Prof. R. V. Jones of Aberdeen University has been appointed Director of Scientific Intelligence at the Ministry of Defence. This is a sure indication that the Government has accepted the view that British intelligence, and counter-espionage and security measures, are capable of improvement on the scientific side, and is planning accordingly. During the war Prof. Jones saw service as Deputy Director of Intelligence Research at the Air Ministry, where he and his associates did brilliant work.

An ex-student of Lord Cherwell, it is clear from Churchill's memoirs of World War II that Prof. Jones will have direct access to the Prime Minister whenever he needs it. A chapter of Volume II of the memoirs (*Their Finest Hour*) is devoted to wartime scientific problems and achievements which particularly interested him, and in this chapter Churchill refers to Prof. Jones in connexion with the German navigation aid known as the Knickebein apparatus. This device was designed to bring the bombers over their target in spite of fog, cloud or darkness. On August 23, 1940, the Knickebein stations on the French coast were trained on Birmingham, and a large-scale night offensive was launched against the Midlands. According to Churchill, the radio beams from these stations were either deflected or jammed so that they were rendered useless for navigational purposes, and for the next two critical months "the German bombers wandered around England bombing by guesswork, or else being actually led astray". He adds that the British counter-measures, added to the normal bombing error, had the result that not more than one-fifth of the German bombs fell within the target areas. "We must regard this as the equivalent of a considerable victory, because even the fifth part of the German bombing which we got was quite enough for our comfort and occupation," says Churchill, and this victory forced the Germans to fall back on pathfinder tactics. The German chief responsible for this side of the Luftwaffe's activities later admitted that "he underrated the British Intelligence and counter-measures organisation". Britain retained her initial lead so far as radar devices were concerned, and this achievement, which greatly increased the efficiency of the R.A.F. both as a striking force and as a means of intercepting enemy raiders, is a feather in the cap of Prof. Jones.

Krilium: A New Soil-Improver

Just before this issue went to press the announcement was made to the American Association for the Advancement of Science about the use of certain synthetic polymers in improving soil structure for agricultural and horticultural use, and also for controlling erosion of soil by rain. The commercial products will have the trade name 'Krilium'. The statement about Krilium was made by the president of the Monsanto Chemical Co. of St. Louis, and there was also a technical symposium about the new soil-improver which was introduced by Dr. C. A. Hochwalt, vice-president in charge of the company's research and development.

Krilium (which is pronounced so that it rhymes with trillium) is described as a synthetic poly-electrolyte. "The product is a chemical soil conditioner which for the first time radically and immediately improves soil structure," Dr. Hochwalt said. "*It is not a fertiliser.*" He said it was developed as the result of original research at Monsanto's



Above: *Monsanto chemists show what happens when equal amounts of water are worked into ordinary clay soil* (left) *and into ordinary clay soil treated with Krilium* (right). *Notice that in picture* 4 *moisture is squeezed from the Krilium-treated soil, and that even after squeezing* (picture 5) *the Krilium-treated soil remains spongy, crumbly and workable. Untreated soil, seen in the left of each pair of pictures, remains muddy and unworkable.*

Left: *Radishes sown in untreated soil* (right) *and in soil treated with Krilium* (left) *show dramatic contrast. Note sparse germination in untreated soil which shrank and dried to a hard crust after watering. Better germination resulted in Krilium-treated soil, which was watered in the same manner as the untreated soil.*

Central Research Laboratories in Dayton, Ohio. It is being tested on a large scale by the company and also by some eighty technical organisations in various sections of the United States, including universities and federal and state agencies.

"Krilium is expected to have wide application as a soil conditioner in home gardens, truck farms and greenhouses," Dr. Hochwalt said. "It also may be useful in commercial agriculture. In addition to its other advantages, the new conditioner is highly resistant to bacterial decomposition." It is also claimed to be an effective and economical agent in control of rain-erosion problems created by major civil engineering projects involving the movement of large quantities of earth, such as highway, railroad and airfield construction. It also shows promise in the control of spot-erosion problems in productive agricultural areas.

One pound of Krilium, Dr. Hochwalt said, has essentially the same effect on soil structure as 200 pounds of peat or 500 pounds of commercial compost. The cash value position of Krilium, which will sell at under two dollars a pound in America at the outset of its production, is further improved by the fact that it is much more resistant to bacterial decomposition than either peat or compost. Because of this lasting effect on soil structure, it is believed that its beneficial effects when used on farms will be more persistent. The new conditioner is, in effect, a synthetic substitute for natural humus normally present in fertile soils but lacking from silt and clay soils with little or no 'crumb structure'. Chemically it is related to the synthetic fibre called Acrylan.

The primary effect of Krilium is to form and also to stabilise natural soil 'crumbs' against the dispersing or slaking action of water. The new conditioner improves the aggregation of poor soils, in which the size of the aggregates may range from the size of dust particles to that of clods, but which have a poor capacity for holding water. (In well-conditioned soils, the soil aggregates retain an optimum size ranging from a pinhead to a pea.) While any soil can be worked up mechanically into a porous, loose structure, which is something the gardener does when he prepares a seed bed, only a soil of good tilth retains its structure and remains a favourable medium for plant roots after heavy rainfall. Soil with poor structure, as it dries after rain, tends to slake down to a shiny, smooth, crusty surface. Such soil shrinks, crusts and cracks, with a reduction in germination of plants, crops or flowers; the latter's time of emergence may be delayed, or they may die in the struggle to push through the hard crust.

Good structure also means good aeration, which is necessary for healthy root growth and root action. Often plant nutrients present in the soil cannot be used because of the lack of oxygen associated with poor soil structure. In this connexion the application of Krilium, which is not itself a nutrient, provides better utilisation of plant nutrients, whether the latter are already in the soil or are added at later periods in the form of cheap inorganic fertilisers. Improved aeration also encourages desirable soil microflora and may be instrumental in reducing fungal and other soil-borne diseases, such as damping off and root rot.

By improving soil texture other important moisture relationships are affected. A soil with a porous, spongy structure allows more rapid infiltration and percolation of water. When the soil's surface is not sealed off by slaking after rain, less water is lost by surface run-off, and so more water filters down for storage in the subsoil. From the subsoil the water slowly rises, later, to the growth zone. In tests Krilium has improved water infiltration and percolation as much as 300%. A treated soil's capacity to hold water against drainage is increased without loss of aeration. While the soil drains freely, it retains as much as 30% more water, after the soil has become saturated and the excess water has drained away, because of extra air space inside each individual soil aggregate. All this increased water is available for plant growth. Krilium-treated soil also shows an increased ability to hold water against evaporation. Cracks and fissures, which ordinarily permit water vapour to escape from soil, are less liable to arise. Experiments show that a treated soil took twice as long to lose half its moisture as an untreated soil of the same type.

Use of Krilium not only saves the water in the soil but also helps prevent the harmful accumulation of water-soluble salts in the surface soil in irrigated areas, it is claimed. The new conditioner shows promise in the reclaiming of saline and alkali soils.

One of the most important results claimed for Krilium is the increased ease with which treated soil can be worked. This applies to tillage with farm implements such as ploughs, and also with gardening implements. Treated soil can also be tilled at higher moisture levels in early spring without puddling. Greater workability is obtained even with a clay soil, Krilium actually changing the tight, sticky character of the clay.

The rate of application, which depends on the type and degree of soil improvement desired, ranges from concentrations of 0·02% to 0·1% (by weight of soil). While additional studies are being made to determine the best application methods for Krilium, tests already made indicate that in agriculture and gardening the new conditioner may be spread on the soil surface at a uniform rate. It is preferable that both soil surface and conditioner should be dry at time of treatment. As minute amounts of Krilium are effective, it may be desirable to dilute it. Then the conditioner, which is a non-toxic, free-flowing powder, should be mixed thoroughly into the soil, to the desired depth, by means of a disk or rotary tiller, or hand implement. Adding sufficient water to soak down to the treated depth helps achieve the maximum effect. If rainfall is expected, treatment may be made just prior to anticipated rain. Seeding can be done conveniently before watering.

As a cheap agent for controlling erosion of soil by rain, Krilium is simply spread evenly on the surface. After it becomes wet, it forms a water-permeable film on the surface of the ground during the period necessary for establishment of a permanent cover crop in erosion control. In addition to providing marked resistance to the erosive action of water, the product improves conditions for seed germination and subsequent growth of the grass or vegetative cover always necessary for permanent protection against erosion.

The product is still in the development stage and will not be on the market in substantial quantities before 1953. (It should be noted that the report published above is a

summary of the details about Krilium released at the A.A.A.S. by Monsanto. When information confirming these claims, or more detail about particularly interesting aspects of Krilium's use become available, we hope to be able to find space to publish it in DISCOVERY.)

A Chemical Footnote about Krilium

AFTER the above note was printed, further details were released about Krilium which shed some light on the chemical mechanism which renders it a soil improver. It is a polymer based on acrylonitrile, so that its commercial production has something in common with the synthetic resin "Perspex", and the synthetic rubber called "Perbunan". Krilium is soluble in water, and it then dissociates to yield poly-anions—that is, large ions carrying many electrical charges. Each ion carries a hundred or more electric charges, as compared with the single charge on sodium ions, or the triple charge on aluminium ions. Aluminium and ferric ions are well-known soil-improvers, causing flocculation of clay; a poly-anion, as one would expect, is even more effective in this respect than ions carrying only three charges. Experiments with Krilium indicate that the ultimate level of adsorption of Krilium ions by clay is about equal to the anion exchange capacity of the clay. Krilium may be considered as a synthetic substitute for the natural polysaccharide or polyuronide resins present in humus, but it is about ten times more resistant to bacterial decomposition.

Sidelight on Biological Warfare

RECENTLY there have been many attempts to make people's flesh creep by means of hints that have been dropped about new and terrifying weapons of biological warfare. This campaign, the object of which is to create the impression that the atomic bomb has been rendered obsolescent by discoveries in the realm of biological warfare, has been partially successful, not because of the actual progress made at places like Porton but because of the fact that human beings are always more fearful of the unknown than they are of phenomena within the compass of their experience or knowledge.

To assess the strategical and tactical significance of the biological warfare weapons now available is a matter of peculiar difficulty, for two main reasons: firstly, all the new weapons are official secrets; secondly, not one single weapon has been used in the field this century, unless one stretches this category of military weapons so as to include poison gases. In practice, the untried weapon is a vastly different proposition from the weapon which has been tested in actual warfare; a rare exception to this rule was the atomic bomb, but it should be noted that the first two atomic bombs were dropped on targets so vast that lack of experience in its military use could not matter.

There is, however, one important piece of induced evidence which suggests that the capacity of biological warfare weapons to alter a military situation in the decisive way that atomic bombs have done has been exaggerated. This evidence derives from the consideration of the peaceful applications which have emerged from biological warfare projects. One such project was the intensive wartime search for chemicals, including the so-called plant hormones, which might be used to ruin the farm crops of the enemy. Three plant 'hormones'—2,4-D, MCPA and 2,4,5-T—have now been widely used as weedkillers. Yet they have not revolutionised farming practice, except in a limited way for a few special crops, and they show little promise of even doing so; it is not a question of farmers being too conservative, for one meets many farmers who have given these novelties a fair and thorough test and have then returned to cheaper old-fashioned weedkillers that give reliable results, or who prefer to rely strictly on cultivation methods for controlling weeds.

Another example, this time from Australia, shows how resolutely a living organism can hang on to those niches on the world's surface which thousands of years of evolution have made it fit so perfectly. Every single trick known to experts on biological warfare has now been used against the rabbit; the result?—the rabbit is still increasing its numbers. In 1950 germ-warfare was tried on a vast scale. A strain of virus which causes the killing disease known as myxomatosis in rabbits was found, and steps were taken to accelerate its speed. It was thought that if a sufficient nucleus of artificially infected rabbits could be created, the disease would be spread far and wide by flies, midges and fleas which 'prey' upon rabbits and the artificial epidemic so started would kill off a substantial proportion of the rabbit population. The campaign was planned like a military operation, and all the agricultural and scientific organisations with knowledge and experience relevant to the project were brought in—including all the State departments of Agriculture, the Lands departments of Queensland, Victoria and South Australia, the Commonwealth Department of Commerce and Agriculture, the University of Melbourne, the Australian National University, the Hall Institute of Medical Research and the Commonwealth Scientific and Industrial Research Organisation. High hopes were raised when the first reports came in about the rabbit casualties resulting from a limited attack in the region shown in the accompanying map. The reports indicated that since the virus had been released in October 1950 the disease had spread roughly 1000 miles from east to west, and almost the same distance from north to south. Production of the virus was stepped up, and the abundant supplies of it which became available were used to infect hundreds of other rabbits. Yet this more concentrated attack has failed, which is more than disappointing as the original skirmishing had seemed to be so successful. This kind of thing is, of course, typical of what happens when one works with living organisms; so many variables are involved, when one has to deal with an intricate nexus of biological factors, that the certainties of the physical and chemical sciences do not apply. Biological problems are nearly always more complicated than the kind of problems with which the other sciences are concerned; biological experiments are harder to design and carry out for that very reason, and generally it takes a long time before any definite conclusions can be reached. (The biologists' method of control experiments, for example, increases the amount of work involved, and unless large teams of biologists can be deployed conclusive results capable of large-scale application take a long time to obtain.)

A final example which drives home the point about the

Close-up of a flying swarm of Red Locusts in Tanganyika, where it is becoming increasingly difficult to control the pest by means of chemicals.

difficulties of controlling living organisms is afforded by the Red Locust. A lengthy and very expensive campaign has been waged against this pest in Africa, which was described in detail by Dr. D. L. Gunn of the Anti-Locust Research Centre in a lecture to the Royal Society of Arts two months ago. Chemicals of ever-increasing toxicity have been used to poison the Red Locust; for example, dinitro-ortho-cresol at a strength of 20% (which is stronger and more poisonous than the DNOC normally used in Britain against insects) has been used, and this appears to be capable of clearing territory occupied by swarming locusts at the almost incredible rate of 3–5 acres per minute. Yet Dr. Gunn's conclusion about the efficacy of chemical control of locusts is this:

"Chemical control of insects has to be carried on year after year and, if anything, intensified because of its interference with the natural balance of population. It never seems to get cheaper. It might even be suggested that the recurrent upsurge of Red Locusts in the Rukwa during the last 10 years has actually been due to methods of control that have interfered with the natural action of parasites and other diseases."

His remarks about the possibilities of biological control of this pest are also worth quoting:

"As an alternative to chemical control of insect pests, most people think of biological control, meaning natural control of population size by predators, parasites, and other diseases. First of all, it should be understood that we know practically nothing about the effects of predators and diseases on population changes in the Red Locust. There is some information about species and that is about all. We know that the populations of the outbreak areas did fall to low levels during the early 1930s, without human intervention, and at the same time as the plague was still intensifying all round. We also know that there were many reports of hoppers dying from the effects of a fungus *Empusa grylli* in 1934, just before the peak of the plague; but we do not know why the plague declined. We have no evidence to show what contribution is made by weather and what contribution by diseases and predators to checking the Red Locust, either during a plague or in its permanent survival areas. It seems worth while to devote some attention to diseases and predators both inside and outside the outbreak areas. If some important parasite is missing only from the outbreak areas, the reason for its absence may be found and that reason removed; and it is also possible that chemical control methods could be adjusted to favour specific parasites. In the past, however, the greatest successes of biological control have been cases when the pest and its parasites have both been imported across a zoogeographical barrier. It would be unwise, therefore, to devote the main research effort to biological control."

The three examples just quoted demonstrate the difficulties that have been encountered in attempts to control by chemical and biological methods three kinds of living organisms. The difficulties connected with biological warfare are of a different order altogether, for here the organism concerned—man—will have well-designed countermeasures which will provide defence against biological warfare weapons. A scientific consideration of the many problems involved provides many more arguments *against* the use of biological warfare weapons by the military than in favour of it. This is probably one case where expenditure on a particular line of military research will only be justified by the peaceful by-products of that research; should its results ever be used in actual war those benefits would be cancelled automatically.

Two Biologists went to War

In Britain, biology is still the Cinderella of the sciences. The pattern of our history has reacted with the innate complexities of this science and the difficulties involved in carrying out biological research, and these factors have led to a general neglect of biology relative to physics and chemistry; a striking example of this fact was provided by the way penicillin, after its discovery in Britain, had to cross the Atlantic before it could be put into large-scale production, America having the knowledge of the relevant biological specialism called industrial microbiology which Britain lacked. Post-war developments have aggravated the disbalance between the sciences; for instance atomic energy projects in Britain and the U.S.A. employ five per cent of all the scientific manpower available in the two countries, and nuclear physics continues to attract more and more scientists. The disbalance is a bad thing, not only for biology but for the progress of science as a whole.

The ambitious schemes for technical assistance as outlined in the Colombo Plan, in America's Point Four programme and the various programmes of the United Nations and its special agencies, cannot materialise without the most effective deployment of biological knowledge and of biological experts. Yet the corps of trained biologists available within the British Commonwealth is certainly not deployed to the maximum advantage.

The Ministry of Labour, in its report on the supply and demand for biologists, claims that too many biologists are being trained in Britain. On the other hand, Sir Henry Tizard's office has reported gaps in the research and development front which can only be filled if many new biological posts are created, and a similar call for more biological research and development was made by the Royal Society's conference on the research problems of the British Commonwealth. It is to be hoped that the Government will note the contradiction of the Ministry of Labour's report by the Tizard report and by the Royal Society, and call for a full investigation of the true facts of the situation. Ever since the 1914 War Britain has tended to waste the biologists she has trained, and this tendency has still not been reversed. In* DISCOVERY *files there are numerous cases recorded which show the nature and extent of this wastage, and at this critical time, when the general call for financial economies may effect the use of biologists, we feel the publication of two typical case-books may help to call attention to this matter. We do so because we feel that any economies which led to unemployment of biologists would be false economies.*

Case-Book No. I

I BECAME a biologist at the taxpayer's expense, entering the university on a Government scholarship. Three years later, in 1938, I graduated with honours in zoology and found myself faced with the usual problem of what to do next. During my last year I had made a tentative approach to the subject of parasitology but, on the advice of my professor, I abandoned this and began to study a problem of even more direct economic importance. As the work developed it became clear that a great deal of fundamental research would be necessary before any real progress could be made with the problem as a whole. Various bodies promised grants towards the cost of this research but by the time the preliminary report was completed the nation had a war on its hands. I was told to 'stand by'; for it seemed certain that, in view of the knowledge I had gained in preparing the report, my services would be required. But I, like so many others, had counted on the Government's having plans to meet this emergency. Too late I discovered that no such plans existed. As a patriotic gesture, several universities loaned biologist members of their staffs to the Government in order that the work might continue: the Government accepted this offer and accordingly made no allocation for salaries. My scholarship had expired, I was not a salaried member of my university, I had no independent income. I was thus effectively cut off from my job although there was the work for me to do. My only contribution lay in the loan on request of my report to one of the people more fortunately placed than myself.

In October 1939 the B.B.C. broadcast an appeal to all men with technical or scientific qualifications to place their services at the disposal of the Government. I was one of those who responded to this appeal and in November 1939 I was interviewed by my University Joint Recruiting Board. Because of the economic importance of my special study I was placed in 'Category A' and reserved indefinitely from military service. The J.R.B. was unable to promise me immediate employment but told me to 'stand by'. At the beginning of May 1940 I received calling-up papers. Since my professor was at this time hopeful of getting me a post with the Ministry of Food, I telephoned the J.R.B., told them what had happened and, on the very next day, received notification that my call-up was cancelled. This was the solitary example of real efficiency I encountered. But the negotiations with the Ministry of Food fell through. For financial reasons, if for no other, I could no longer continue in this 'reserved non-occupation'. I sought an interview with the Secretary of the J.R.B. and asked to be released in order that I might join the R.A.F. for aircrew duties. Permission was refused: I was told that my potential value to the community was too great and that I had better find myself temporary civilian employment until my services were required in my professional capacity.

It was at this point that I made my biggest mistake. Instead of making myself a thundering nuisance to the maximum number of people until somebody gave me a job to keep me quiet, I took all of this at its face-value and

* See the two-volume report entitled *The Royal Society Empire Scientific Conference (June–July 1946)*, published in 1948.

went away to do what I could for myself without troubling anyone else. Naturally I wasn't very successful. As soon as a potential employer learned that I was subject to Ministry of Labour direction, I had, in the jargon of the Service I later joined 'had it'. Even this experience did not teach me my lesson. Rather than add to the burden of over-worked Civil Servants I resolved to take any unskilled job I could find, something I could leave at a moment's notice when the Ministry sent for me, without embarrassing my employer. After all, I assured myself, it didn't much matter what I did for a few months as long as I earned a little money by doing it. Finally I went to work for an acquaintance of mine, a haulage contractor, who had an Air Ministry contract to salvage crashed German aircraft. Within a short time I was promoted to the rank of heavy lorry driver, in which capacity I continued until I was called up for the second time in October 1942. Most of my driving was done on special articulated vehicles for transporting cased aircraft, marine craft and other abnormal loads, in consequence of which I spent some time at an aircraft factory in the Midlands as an "Air Ministry expert in the haulage of aircraft by road". I came, of course, under the Schedule of Protected Industries which meant that I could not leave my job other than with Ministry of Labour permission. To secure this permission I should have had to show that I had a more suitable job to go to—and finding a job when you're working a 70- or 80-hour week anywhere between South Wales and the Western Highlands is no easy matter.

During this period I received notification of perhaps half a dozen vacant posts from the Central Register, all of them under County War Agricultural Executive Committees. In each case my application was turned down, due, I must assume, to my lack of agricultural experience. There was, however, one exception—and thereby hangs a tale. I received from my local Army Recruiting Centre a form which read: "Further to your application for enlistment in the R.A.S.C., you are required to report at this Depot for attestation on . . .". Having made no such application, I went along to see what had happened. The captain who interviewed me was at first as mystified as I but, on making enquiries, he discovered that my name had been sent down by the Appointments Branch of the Ministry of Labour with instructions that I should be *invited* to join the R.A.S.C. No official form being available to deal with this contingency, the Orderly Room had used the next best thing! But this had solved one puzzle only to present another. The Appointments Branch knew of my zoological qualifications, but they also knew I was earning my living by driving lorries. In which capacity they had put forward my name? And why the R.A.S.C.? Did they want zoologists or drivers? I discussed these questions with the captain who was quite certain that the Corps had no need of a zoologist and that it must therefore be the other thing. I pointed out that, as a driver, I was doing specialised work of national importance in which I was experienced, to which the captain replied by suggesting that I should write to him formally declining the invitation. I did so, expecting to hear no more of the matter. When I was called up into the R.A.F. in 1942, however, I paid a last visit to the Appointments Branch. My card in the Register there recorded the surprising information that I had been in the R.A.S.C. for the last three months! It was not until some time later that I learned the truth of the matter. The R.A.S.C. did require a zoologist as an inspector of food dumps—a post I was well qualified to fill. It ultimately went to an entomologist friend of mine who, having served as a lieutenant in an infantry regiment and later on Intelligence, had been invalided home from Malta with amoebic dysentery.

The first eleven months of my service in the R.A.F. were spent in trying to persuade the authorities to make use of such qualifications and aptitudes as I possessed. They were not interested in me as an expert in the haulage of cased aircraft but only as a potential driver of 60-foot vehicles; they accepted me, after a test, for training as Link Trainer Instructor, only to reject me without giving a reason before I went on the course; they refused to take me as Laboratory Assistant on the grounds that I had no qualifications in Pathology (although I knew another man who had been offered direct entry on the strength of eighteen months' experience in the laboratory of a steelworks); they told me I was ineligible for a commission as Photographic Interpreter because, despite slight colour-blindness, defective vision and low blood-pressure, I was officially fit for aircrew duties—a point on which I had five opinions, all different; they declined to entertain the idea of transferring me to T.R.E. who, I was given to understand, were at that time crying out for trained personnel. Finally, having employed me as squadron office boy, poster artist, heavy labourer in a bomb dump and stock-control clerk, they posted me on a ten-and-a-half-months' course of training for the trade of Wireless Mechanic—a subject of which I knew nothing and cared less. Fortunately the change of atmosphere agreed with me and, to my surprise, I did rather well at it. After six months in the 'ab initio' school I was retained as instructor for a further six months. This was followed by eight months in the 'advanced' school, partly as trainee and partly as maintenance mechanic, whereupon I was posted overseas to Italy. I spent a pleasant ten months in the Naples area as wireless mechanic on a station which had no real need of a wireless mechanic and then migrated to the north where, as an Educational and Vocational Training Instructor, I taught Physics and Chemistry to mixed classes of Army and R.A.F. personnel.

Class 'A' release has now restored me to the bosom of my family. In 1939 I was optimistic enough to anticipate that a good use would be found for the services of one zoologist. In 1946 I have enough of that optimism left to hope that a place in organised society exists for a zoologist who can drive anything from a Topolino Fiat to an eight-wheeled Diesel, who can repair and construct many types of radio gear and who, for that matter, can even play a piano. Or shall I find it necessary to undertake a course of training as an architect?

Case-Book No. 2

Today, personnel selection is coming into its own and everyone's aim is that the square pegs should be kept away from the round holes. That, anyway, is the theory. But what about the square pegs which have been driven home?

Are they to remain so, with their edges burred and blunted, of no use to anyone, or are they to be allowed to fulfil their function, after suitable treatment?

Here then is the tale of such a square peg. No doubt some will say, "It was his own fault. He should have got himself reserved", but I will pass that without comment. Or, "What is all the fuss about? There are Government schemes and grants for rehabilitation." True, but our lack is not academic knowledge, but that somewhat vague thing which goes under the name of experience. In any case, economic and other problems must often be taken into account.

The story begins, like so many others, in September 1939, with one square peg, a graduate of a year's standing, still looking for a square hole; the possessor of a reasonable zoology degree, and yet apparently unwanted. Then when the thing that had been threatening so long came to pass, he thought that at last a zoologist would come into his own, with so much work of a biological nature that would obviously need to be done in the "interests of national security". The reader will see how innocent the writer was in those days.

As it seemed the proper thing to do, this square peg immediately went before that phenomenon known as a Joint Recruiting Board. They decided that it was better that he should continue in his profession, notwithstanding that he had no post. Their decision, however, was not a clear-cut case of reservation and consequently he was forced to admit to prospective employers that he was liable for military service at some future date. As usually the vacancy had been caused by someone being called up, he did not make much impression.

Eventually, as it seemed so absurd to be unemployed in wartime (although remember that this was early 1940), he took a job in an aircraft component factory, drilling countless holes in, to him, meaningless bits of metal. After a short time, he came to the conclusion that the Army would offer a more interesting job, especially as he thought that with his qualifications, he would have no bother in getting into either the Royal Army Veterinary Corps, or Royal Army Medical Corps. Both, however, refused to have anything to do with him. It seems absurd today, this difficulty he experienced in getting into the Army. It was not until much later that it occurred to him that by registering as a conscientious objector, he would probably have been pushed into the R.A.M.C., whereas now he was unable to volunteer for it.

Time went on, and he had recourse once more to the Joint Recruiting Board, informing them that it was rather pointless for them to consider him to be reserved when there were no posts, and suggesting that they should recommend him to be called up into the R.A.M.C. However, the Board could not see what possible use a biologist could be in the Forces, and the fact that he had once done Electricity and Magnetism as part of his intermediate B.Sc. proved his undoing. To their minds (they were physicists), the Royal Signals was obviously where his talents lay. Their decision was that he should have to wait until his normal call-up, when the recommendation that he be drafted into the Royal Signals would go forward.

Nothing more happened for some time, and at last he asked that his call-up should be expedited. This had some effect, and soon he was in the Royal Signals. Here again, his scanty knowledge of electricity decided that he should be an electrician. Having been recommended by a Recruiting Board, he was interviewed by a board regarding his potentialities as an officer. (This was of course before W.O.S.B.s.) Things went quite well until his father's position was considered, when the temperature dropped considerably. Having had the bad sense to choose a father with the incorrect social background, he was to apply again later. This he resolved never to do, a thing he never regretted. Apart from any principles involved, anyone in the Services interested in the biology of his fellow men should realise that his place is amongst them, in the ranks. In any other position he usually mixes with a type which he knows already, and which is not usually very interesting, while he sees his 'inferiors' only in their guarded moments.

To return to the subject; service overseas took up the next four and a quarter years, first the Middle East and then Italy. The time between the return from overseas and release was filled in by six months' occupational duty in Germany. Once having been classed as an 'A' tradesman, transfer to any other arm was out of the question (at any rate, until comparatively recently), while always being with an independent unit, continually on the move, meant that one never saw Army Council Instructions, etc., which might have been of interest. For instance, recently in an interview, a candidate was asked why he had never gone before a W.O.S.B. when Commanding Officers had instructions to put forward all graduates under their command. This was the first he had heard of it, but the interviewing board, not knowing the way the Army works, seemed most unbelieving, and probably put it down as his own fault, with an adverse mark. It is a great pity that these interviewers have not a small fraction of the experience and knowledge of the ways of man and the world outside their immediate little orbit, that some of the people who come before them have.

The 'Backroom Boys', to use a horrid but understandable expression, have quite rightly had their praises sung; but it should be remembered that they were doing their own job and gaining experience with resources unheard of in peacetime. It is true that they took risks at times, but he is a poor scientist who is not prepared to do that in war or peace, if by doing so, he furthers his knowledge.

Now they sit back somewhat smugly, interviewing those who spent the time not in the backroom, but in the front garden, who have had the bad taste to come out of it alive, and the even worse taste to expect a scientific job. Their attitude should be "There, but for the grace of God, went I", but we cannot help feeling that it is more like "What do you expect, after having got mixed up with the Services". We admit the lack of specific experience but should we be penalised for it? On paper, we agree we are not experienced but the difference between theory and practice is one of the first lessons learnt in the Army. We realise that a row of campaign stars does not make up for this deficiency but at least we should be given fair opportunity, and our capabilities judged by not a cursory interview, but over a period of time. Let us at least have a chance of becoming what we might have been.

The Nature of Quicksands

C. L. BOLTZ

QUICKSANDS are subject to rumours and scares, especially during one's childhood, yet it is a task to find anyone who has first-hand experience of them. So often it is the other person, the absent informant, who is the source of the news. Quicksands, therefore, merit some attention, even if only to clarify a few of the ideas and state some of the known facts.

The question: What is a quicksand? could be better phrased as: When is a solid not a solid? The answer to this question, though posed as a riddle, will provide us with some scientific data.

At one time there would have been little hesitation in dismissing the question as frivolous, for scientists of last century thought, they had all the answers. There were three states of matter, namely, solid and liquid and gas, and each had its own separate laws. That was that; it was dogma; no one in his senses could doubt it. Nevertheless, disconcerting facts accumulated to show how little we know despite the immense amount of knowledge we had acquired. Not a single known gas obeyed the gas laws; so an 'ideal gas' was postulated. Some 'solids' were shown to have properties supposed previously to have belonged to liquids. For example, glass 'flowed', very slowly it is true, if subjected to a force tending to change its shape. This fact was fitted into the dogma by saying that glass was not really a solid, but instead a highly rigid liquid. Quite recently Sir Lawrence Bragg said that a metal is "more like a crystallised liquid than a solid". The work on plastic materials in the past ten years or so has added its bit to show that there is a realm in which substances have some of the properties of solids as well as liquids. Thus the old rigid demarcation has broken down; we know that there are intermediate stages. Moreover, there are materials that show properties more like those of a solid in certain circumstances and more like those of a liquid in others, apart from any change in temperature. Quicksands are such materials. We can without risk of laughter from scientists now answer our riddle thus: "When it has some of the properties of a liquid."

The flow-properties of substances have become of increasing importance in recent years both because of their bearing on 'pure' science, or the pursuit of truth, and their applications in commerce and industry. In dairying, for example, the change from milk to butter and cheese involves many problems of flowing and setting. So successful have the studies been that we now have artificial milk and artificial butter (margarine). The branch of science concerned with these matters has grown too big to be merely a part of physics or chemistry, and has been given a name—rheology. The rheologist is in great demand today. The movements and textures of soils are his concern. So are quicksands, for they show properties possessed by flowing substances. We therefore expect to find that some of the discoveries of rheologists can be applied to the examination of the problem inherent in the questions of the first paragraph above.

Let us first see what sort of properties liquids have. The Latin poet Lucretius 2000 years ago wrote (in *On the Nature of Things*, W. E. Leonard's translation):

> To suck the poppy-seeds from palm of hand
> Is quite as easy as drinking water down,
> And they, once struck, roll like unto the same.

In this he showed that small particles free to move about in relation to each other but not far enough apart to be able to travel a distance greater than the size of the particle had some of the properties of a liquid. Robert Hooke in the seventeenth century devised an apparatus to demonstrate this. Some twenty years ago or so, the late Sir William Bragg modified Hooke's apparatus and worked it to amuse his juvenile audience at a Christmas lecture at the Royal Institution in Great Britain. A shallow cylindrical box three inches deep and ten inches in diameter stood on a wooden plate mounted on ball-bearings so that it could be moved easily. This was joined by a connecting rod to an eccentric point on a small disc driven by a wheel turned by means of a handle. In the box was sand. He took one or two small figures made of celluloid and fitted with hemispheres of lead at the bottom. Anyone who has seen such a figure knows that it cannot be laid on its side or on its head, but will always wobble upright because the centre of gravity is right in the base. When such toys were buried under the sand in the box, and the handle was turned it was not long before the face of the mannikin would emerge from the sand, followed by the rest of the body, just as if it was emerging from water. A cork buried under the sand would bob to the surface. A piece of iron resting on the still surface would sink when the handle was turned. Thus it was shown that moving particles acted like a liquid.

There is a rule for the floating or sinking in a liquid. It is simply this: substances float in liquids of relative density (or specific gravity) greater than their own, and sink in liquids of relative density less than their own. Wood of relative density 0·2 will therefore float in water (density 1), whereas iron of relative density about 8 will sink. The human body has a relative density of something between 0·9 and 1·0, and will therefore just float in water. The floating object has a proportion of it underneath the surface corresponding to the relative density. The wood mentioned above will therefore float in water with one-fifth underneath and four-fifths above. The human body floats with most of it underneath and so a man must see to it that the part above the surface contains his mouth and nose so that he can breathe.

Returning to our notion of a liquid as moving small particles, we can describe several different sorts of 'liquid'. A pure one has its particles as molecules, which are too small to be visible. Such is water, for example. The molecules are held somewhat together by interatomic and intermolecular forces, and yet are free to move about because of their heat energy. With a true solution, the molecules of the solute, also invisible, mingle with the molecules of the solvent. Sugar, for example, dissolves in this

way in water. It is possible to have small particles of a substance denser than its surroundings, yet kept in suspension and prevented from sinking under gravity by the bombardments of the molecules of the liquid. Such particles must be very small indeed. The result is called a 'colloidal solution' or 'sol'. Particles still bigger can be kept for some time in fine suspension, but will settle to the bottom when left quite still for a sufficiently long time. Coarser suspensions can be maintained by constant agitation—that is why we are told to shake the bottle containing medicine. It is possible for some articles of colloidal size to arrange themselves in pattern with the molecules of the solvent, and thus make a somewhat rigid body. Such a substance is called a 'gel'. A gel can often be formed from a sol by cooling. When jam is made, for example, a substance in colloidal form, called pectin, is released from the fruit and forms a sol with the sugar solution, and this becomes a gel when it is cooled. There are also some gels that become sols when they are agitated. This is a very peculiar phenomenon indeed and it has been much investigated by rheologists in recent years. It is called 'thixotropy'. There are many thixotropic substances, and one of them—and this is important for our present inquiry—is clay. If a gel of certain sorts of clay in water is shaken it becomes a sol, i.e. a liquid, but if left to stand afterwards becomes a gel again, quite a strong one. There is another phenomenon associated with some gels; it is called 'false body'. A gel showing this becomes less viscous when agitated, though it does not become a true sol. People using paint have been familiar with this phenomenon for many years, for most paints when left to stand become thick, and yet can be made more fluid by shaking and stirring. Some gels of alumina have this property.

Now consider particles insoluble in water and too big to be colloidal or maintained in suspension normally. Sand, for example, consists of small grains of mineral, chiefly quartz. If such a material is allowed to settle and gently encouraged, the particles pack together into their closest possible arrangement. The material is then firm and 'solid'. The small spaces between the particles can be filled with water or any other fluid, such as air. Because of the friction between the particles there are other possible packing arrangements that are still rigid enough to be treated as solid even if there is liquid in the spaces, though the closest packing is, of course, the firmest of all. If the particles are not allowed to settle into any of the rigid packing, however, then the material has the properties of a liquid because the particles can move round each other.

These preliminaries over, we can summarise the conditions under which some substances have solid-like properties until they are disturbed by man or animal or vehicle. They are: (1) when finely divided dry sand is loosely assembled; (2) when fine sand has plenty of water with it and is kept from settling; (3) when there is a thixotropic gel of clay or other mineral of colloidal size; (4) when there is a false-body gel, especially when we treat sand and water combined as if it were a gel, at which a rheologist might make objections. All these conditions give rise to quicksands, and they can exist separately or in combination, though No. 1 cannot be combined with any other. No. 3 gives what is usually called a bog.

Type No. 1 occurs in deserts. 'Pools' of dry quicksand

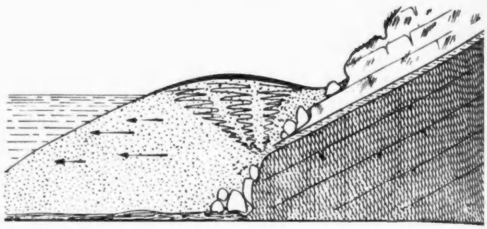


FIG. 1.—One set of conditions which can lead to the formation of a quicksand. The water flows down over the impervious rock and emerges under pressure beneath the sand. It then forces its way slowly upwards and drains very slowly through the sand in the direction of the arrows. A dry firm crust forms on the top of the quicksand where it projects above water level.

bog down vehicles, but men are not by themselves seriously endangered; a man can sometimes jump on such a quicksand and watch the shock wave progress outwards as if the substance were a liquid. Men who have campaigned in the Libyan desert have experienced these quicksands, and can sometimes recognise them by changes in the ripple marks. They are thought to be caused by the geographical formation and development, a view expounded by Brigadier R. A. Bagnold in his book *The Physics of Blown Sands and Desert Dunes* (1941), though he does not explain how it comes about that the sand does not settle and pack.

Type No. 4 when made entirely of sand and water is not really a quicksand, and could be more accurately called 'quaking' sand. Its characteristic is that when agitated by feet it becomes somewhat fluid and will quake like a jelly. It cannot safely be traversed by men without a preliminary preparation, though the danger is not that of a real quicksand or bog. The practical treatment for the passage of men is the laying of carpets of whatever material is available, such as poles and wire mesh, and even brushwood.

In type No. 3 there is often mossy vegetation on the surface, which has hardened into a crust. A man or an animal walking unsuspectingly on this crust breaks through it and is embogged. The resulting liquid is denser than water and slower in its movements. A man keeping his head can therefore float, but the danger is that he gets into a panic, and if he goes at first right under the surface, the time taken for him to rise is too much for his breathing apparatus, and he is asphyxiated before he can emerge. If boggy ground such as this has to be used permanently then some chemical or electrical treatment must be applied to 'flocculate' the colloidal clay, i.e. make the particles join up in bigger lumps and sink. The water above can then be drained off by ditching.

In America there occur what are called 'alkali' bogs such as the Buffalo Wallows of the Great Plain. These apparently have chemical gels and some clay, and so may be either of type No. 3 or 4, or else a mixture of both. They are very dangerous.

Type No. 3 must not be confused with merely soggy ground, which can be made useful for airfields by means of wire mesh.

It seems that the sort most usually encountered is that of type No. 2. Such quicksands occur in river basins, and usually in or near the rivers themselves, which are

slow-moving and sometimes tidal. This type when unmixed with clay has been thoroughly discussed hy Gerard H. Matthes, head engineer of the United States Engineer Department, in the journal *The Military Engineer* for February 1943. The mechanical agitation similar to our shaking of the medicine bottle is done by spring water under some pressure. This forces its way upwards and thus keeps the sand particles 'fluid', though it does not get right to the top because there is slight drainage. So on top the sand looks no different from any other firm sand, but when a man or an animal or a vehicle gets on the surface, it gives way and the interfering object sinks. If the top layer is above the water surface for any time it dries out and forms a deceptively 'firm' crust. One such possible structure is shown in the accompanying diagram (Fig. 1), where water is seen to flow downwards and emerge under the fine sand. If ground harbouring such a quicksand is needed permanently, engineers could trace the source of the water and drain it off. The quicksand would then subside and pack firmly, leaving a hollow on top.

It is seen that with all the types mentioned there are three possible generalisations: (1) The dangerous ground occurs in comparatively small patches, and so can be avoided if there is adequate reconnaissance by men armed with long poles; (2) there is always firm ground not far from the quicksand; (3) the existence of the quicksand or bog is caused by a combination of local conditions, not by any special size or shape of quartz particle, though the smaller the particle and the more rounded it is the more easily can a small pressure of water cause fluidity.

Obviously a man, having a lower density than the quicksand, cannot sink completely or permanently, but there are special factors that make the quicksand seem more dangerous than water and exercise 'suction'. These are: (1) the first shock of plunging downwards through what was thought to be firm ground; (2) the greater viscosity of the 'liquid', i.e. its slowness, comparatively, in flowing; (3) the creation of small vacua when struggling, and the consequent great pressure of sand and atmosphere (the collapse of vacua in sea-water against the propeller of a ship tears holes in the metal); (4) the slow rise upwards when a man has sunk at the first plunge, and the greater slow-moving weight above him; (5) the very short time that a man can survive without breathing. In addition, if there is clay mixed with the sand it is sticky.

So true are these facts that when the quicksand is of the sort last described, a man can get free if he is quick enough at the first shock. Mr. Matthes has given rules for saving oneself. They amount to saying that a man should keep cool and quiet and use his pole underneath him, as he lies flat, in order to give himself some surface grip so that he can free his legs and then roll with frequent rests towards the nearest firm ground. When a large animal or a vehicle is thoroughly embogged, the task of freeing it is a heavy one because of the lateral resistance of the sand and the creation of vacua that make 'suction'.

These, then, are such facts and opinions as can conveniently be set down in non-technical language. It can be seen that there will come a time, and that not very far away, when all the facts about the various conditions known as quicksand will be known and collated. The bogy of our childhood will then have lost not its danger, but its terror. Already the old superstitious fear of quicksand has decreased enough for one Russian worker to be able to state in a scientific journal the rules to be observed for actually building successfully on quicksand.

C. L. Boltz, who is well known to our readers for his articles, broadcasts and books, has just published a delightful collection of scientific essays entitled A Statue to Mr. Trattles *(Butterworths Scientific Publications, London, 1952, 168 pp., 12s. 6d.). The volume takes its title from the case of a merchant who challenged a Board of Trade ruling that he was colour-blind and therefore unfit to hold a second mate's ticket. The upshot of the official inquiry which followed was the complete discrediting of existing methods of colour-vision testing, and it also gave an impetus to research on colour vision. Other chapters discuss such diverse topics as the speed of light, how a chameleon changes colour, the electrophonic organ, Robert Boyle, von Frisch's discoveries about dancing bees, X-rays, and the use of models for scientific purposes. A typical chapter is devoted to the subject of quicksands, and this is the chapter which is reproduced above.*

TIGHTER SECURITY FOR SCIENTIFIC SECRETS

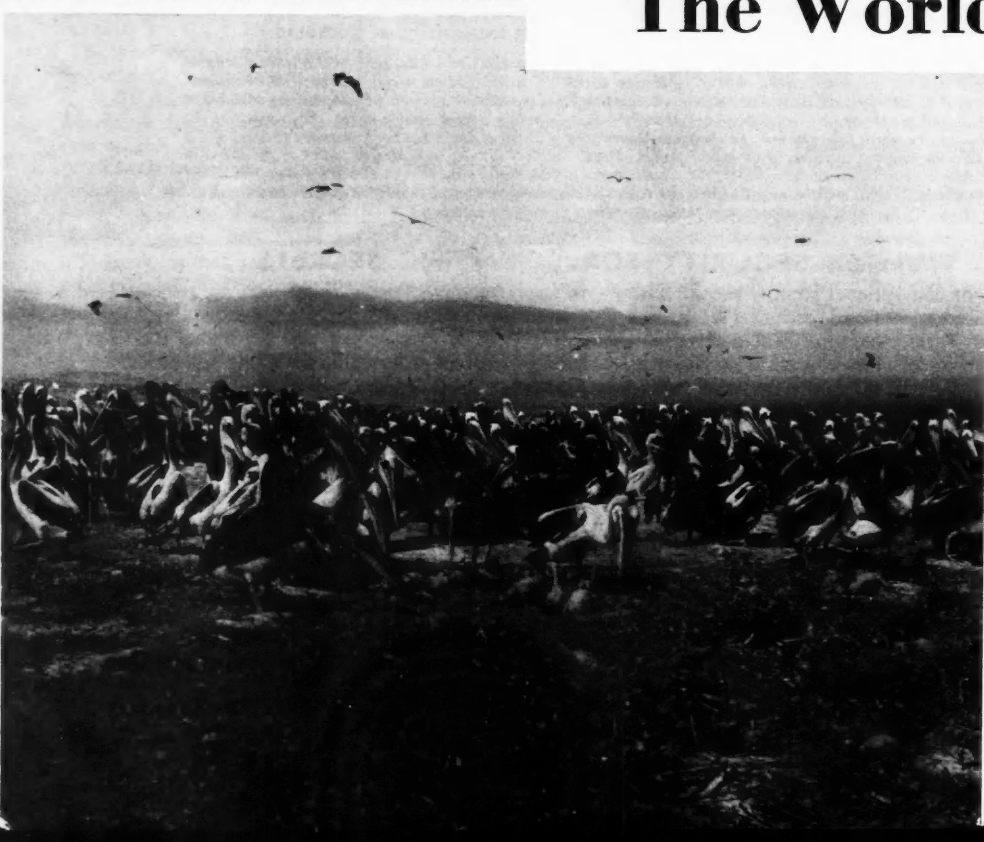
THE ineffectiveness of conventional security measures to stop breaches of official scientific and technical secrets was demonstrated by the Fuchs case, which would never have come to light at all but for clues which the Russians let slip, perhaps carelessly, perhaps deliberately, and which led to Fuchs's detection. A long time after Fuchs's defection, a system was introduced for screening scientists in Government employ. At that time (March 1948) Mr. Attlee, as Prime Minister, stated that experience had proved that membership of the Communist Party and other forms of continuing association with that party "may involve the acceptance by the individual of a loyalty which in certain circumstances can be inimical to the State". It was then decided that the only prudent course was "to ensure that no one who is known to be a member of the Communist Party, or to be associated with it in such a way as to raise legitimate doubts about his or her reliability, is employed in connexion with work the nature of which is vital to the security of the State". The same rule was made to apply to those known to be actively associated with Fascist organisations.

The Pontecorvo case provided proof that the 1948–50 security procedure was still not quite spy-proof, for in September 1950 Pontecorvo escaped behind the Iron Curtain after he had been removed from his Harwell post. Just prior to Mr. Churchill's and Lord Cherwell's departure for America last month, newspapers were discussing the risk entailed in giving any more atomic secrets to Britain; "Britain's Government is careless, if not incompetent, when it comes to ferreting out espionage within her borders, and especially inside her Government offices," was one typical comment.

Now the Government has announced that it is tightening the security screen designed to keep unreliable persons out of secret work. Furthermore, efforts are being made to ensure perfect integration between the seven separate and overlapping agencies responsible for security. Prof. R. V. Jones's appointment (see p. 39) is related to that aim.

The World's Mot Va

Photographed by Rolfmberg, Camer



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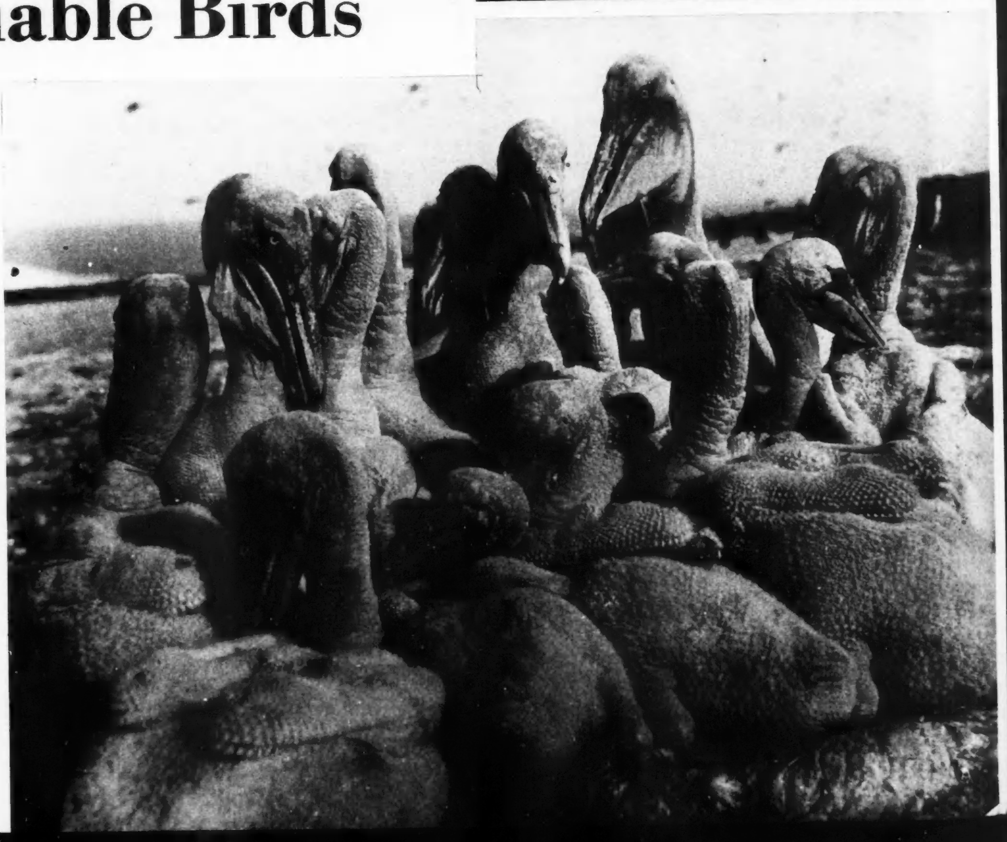

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FIG. 1.—The author looking at some germ-free chickens which have been reared in this steel germ-free chamber. They were introduced as eggs, incubated, and have been fed ever since on sterile food and water. By means of the rubber gauntlets sealed to the chamber, the assistant can handle the chickens without contaminating them.

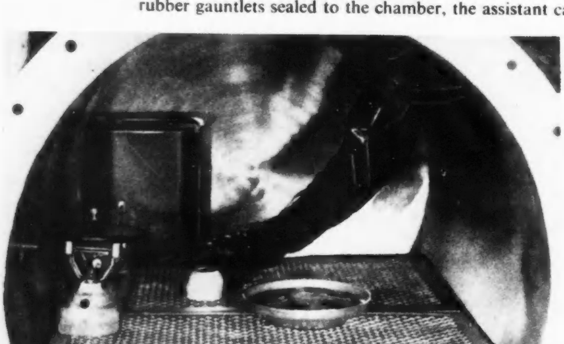


FIG. 2 (*left*).—Interior of germ-free unit for rearing chickens.

FIG. 3 (*above*).—The first chick hatched from an egg laid by a germ-free hen; this chick proved to be germ-free like its parent.

A Germ-free Laboratory

CHAPMAN PINCHER

INGENIOUS techniques have been perfected by microbiologists to enable them to isolate and study bacteria in artificial cultures. It is now possible, by means of a micromanipulator, for a skilled researcher to pick up one single bacterium. He can transfer it to a culture medium which has been sterilised at high temperature without destroying its capacity to nourish the bacterium and the bacterium's millions of descendants. In short, there is a range of almost perfect techniques for studying the behaviour of bacteria *in vitro*. But when the microbiologist progresses to the stage where he injects the bacterium into an animal in order to study its behaviour in a natural environment, he encounters a serious limitation.

He cannot be sure that the subsequent effects he records are entirely produced by the particular type of bacterium he has injected. For no matter how carefully bred or how hygienically housed his test animals may be, they are grossly contaminated by the other bacteria which normally live in the alimentary canal, the nasal passages and reproductive tract. Furthermore, the animals are continually exposed to invasion by pathogenic organisms present in the air and in their food and water.

Until recently microbiologists have simply accepted these limitations, and have done remarkably well in spite of them. But in one extraordinary establishment which I visited recently the challenge to provide completely germ-free animals for research purposes has been taken up with brilliant results. This establishment is known as LOBUND —Laboratories of Bacteriology, University of Notre Dame —and is located at South Bend, a small manufacturing town near Chicago.

There animals, ranging from monkeys to houseflies, have been reared which are entirely free from germs, and these are being used in scientific experiments. The laboratories, which house about 200,000 dollars' worth of unique equipment, are a monument to the foresight and patience of one man—forty-three-year-old Professor James A. Reyniers. As a student at the Roman Catholic University of Notre Dame (which the Americans pronounce Noter Daim!), Reyniers read that Pasteur believed that an animal could not go on living if it were entirely free from germs. He resolved to tackle the immense problem of testing this hypothesis and to study thoroughly at the same time how animals fare under germ-free conditions. His enthusiastic advocacy of this project gained him enough money to enable him to make a start, and he has kept the research going ever since through the fertility of his ideas.

Germ-free Births

The equipment which I saw represents twenty-three years of trial-and-error experiments. Through its use, complex techniques have been reduced to straightforward routines, most of which can be carried through by laboratory technicians.

Each germ-free mammal begins its life as a result of a Caesarian operation performed under aseptic conditions far more exacting than those demanded for human surgery. The mother—an ordinary 'germ-laden' laboratory animal —is prepared for the operation a few hours before she is due to give birth normally. She is dipped in a bath of antiseptic. Her abdomen is shaved. Then she is anaesthetised and tied to the operating table. This table can be raised and lowered by a lever. Immediately above it is a germ-tight steel cylinder through which warm filtered air can be pumped. (Reyniers devised glass-wool filters which can be sterilised and dried *in situ*.)

In the bottom of the cylinder directly over the platform there is a hole slightly smaller than the operating table. This hole is sealed by a transparent plastic sheet which has been heat-sterilised along with the rest of the chamber. When the operating table is raised to its full height the abdomen of the pregnant animal presses against the plastic sheet and projects into the germ-free chamber. The surgeon is able to look straight down at the animal through a glass observation window on top of the chamber, and can operate through long rubber gauntlets which are sealed into the steel walls on each side.

By means of an electric cautery needle he makes an incision through the plastic sheet and through the animal's abdomen. The cut edge of the plastic adheres to the animal's skin, so making an airtight joint. The surgeon then completes the operation and the young are born into the germ-free atmosphere.

A second sterilised steel chamber—a rearing chamber— has previously been brought alongside the operating chamber, and the two have been joined together by means of a cylindrical air-lock. This is really a small autoclave, the inner wall of which can be opened only through the rubber gloves from the inside of the surgical unit. After attachment to the operating chamber the air-lock itself is sterilised by a jet of high-pressure steam. The young are then transferred to the rearing chamber via the air-lock, and spend the rest of their lives in this type of unit.

No Sign of Viruses

Tests have proved that animals born of healthy mothers in this way are entirely free from germs and may be kept germ-free until they die. The scientists cannot be sure that the animals are free from viruses, but so far they have found no evidence of the presence of pathogenic viruses in their germ-free stock.

The germ-free young have to be given almost constant attention from the moment of their birth. The fact that they are slightly premature increases the scientists' difficulties. In the case of rats, for instance, the young must be hand-fed through pipettes every two hours. The only way of achieving this is by day and night shift-work. Reyniers experienced great difficulty in finding suitable liquids on which to feed the new-born mammals. They need to be given some form of milk, but all natural milk deteriorates at the temperatures necessary to ensure that it is quite sterile. The trial-and-error experiments which had to be

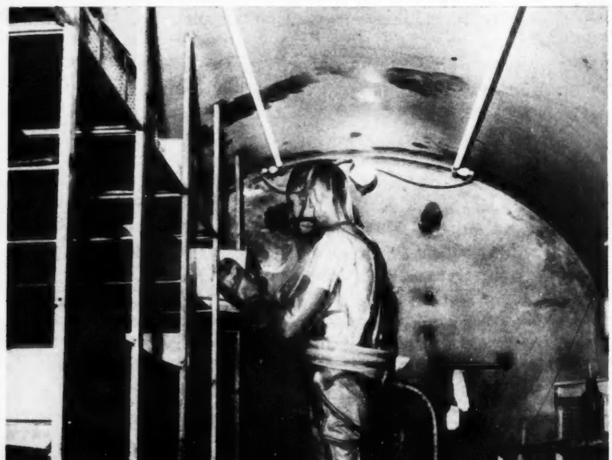
THE GERM-FREE CHAMBER

for mass-producing sterile animals

FIG. 4.—The attendant is sealed into his plastic diving-suit, a hot jet being used to weld the loose seams.

FIG. 5.—In his diving-suit, he takes a disinfectant shower before plunging into the disinfectant bath through which he must pass to reach the germ-free chamber.

FIG. 6.—He has now entered the chamber, and is seen taking out one of the cages in which mice and similar small experimental animals are housed.



done before a synthetic substitute for rat-milk could be found took many months. But Reyniers and his team eventually solved the problem, and later they were able to find suitable synthetic milks for other mammals.

The milk is put into the air-lock which is then closed and sterilised by super-heated steam. During this process the rearing chamber is cooled with a stream of water to protect the animals inside. The inner door of the air-lock is opened and the food is taken inside the rearing chamber. At the same time any debris is pushed out into the air-lock which is then closed.

Once the animals have been 'weaned' they are reared on food and water kept in sterilised cans which are opened inside the chamber. By using the air-locks, animals can be moved from one rearing unit to another.

Under these conditions, rats have been reared to full sexual maturity and have bred successfully producing germ-free offspring. These creatures are germ-free in every sense; their alimentary canals, reproductive tracts and skin are completely sterile. It is not possible to culture any bacteria from the excrement, which in normally reared animals is largely composed of dead bacteria. When the germ-free animals die they do not decompose in the usual way, but remain in a state of good preservation for up to a week; then auto-digestion (autolysis) by the organisms' own enzymes occurs, and the corpses eventually become mummified.

Germ-free animals are not generally entirely as healthy as normal controls, but the slight differences revealed so far seem to be due to defects in the entirely artificial diet. There seem, for example, to be some slight internal differences in the lymphoid tissue, and also in the structure of the intestines. But some of the latest animals to be reared under these totally artificial conditions are apparently quite normal, showing all the usual criteria of health.

Blood tests have shown that germ-free animals produce no protective antibodies against pathogenic organisms. Weak antibacterial antigens have been demonstrated in some of the older animals, but there is strong evidence that they were due to the presence of dead bacterial cells in the sterilised food. The antigens corresponded to particular species of bacteria which could be isolated from the food before it was sterilised. There seems to be no passage of antibodies from mother to offspring. Germ-free animals have the power to produce antibodies if exposed to infection, but, as would be expected, they tend to be more susceptible to serious infection than normal controls.

After they had produced germ-free rats, the Notre Dame team extended their experiments to include monkeys, guinea-pigs, cats, dogs, rabbits and mice. They have also produced germ-free Bantam chickens, which have laid fertile eggs hatching into germ-free chicks. These are easier to rear than mammals because the youngsters feed themselves immediately after hatching. They present special problems, however, which necessitated further trial-and-error experiment.

Reyniers found he could sterilise the eggshell without killing the embryo by washing it with detergent and then brushing on a solution of mercuric chloride (corrosive sublimate). The eggs are hatched in a germ-free incubator which is so arranged that they can be turned automatically. The young chickens present difficult problems of humidity control, especially as they invariably spill the water in the rearing chamber. But these problems have now been satisfactorily overcome at Lobund. Germ-free Leghorns and Wyandottes, as well as Bantams, have been reared.

After solving the basic problems involved in the rearing of germ-free animals, Reyniers turned his attention to 'mass-producing' them for use in controlled scientific experiments. The result of his efforts in this direction is probably the most fantastic piece of laboratory equipment outside the novels of science fiction. The Notre Dame scientists have designed and built a huge germ-proof chamber in the shape of a steel drum. It can house 800 animals in cages. The infra-red heating system of the chamber is thermostatically controlled. And it is constantly supplied with absolutely sterile air. It is not practicable to feed and attend to the animals in the chamber by the system of built-in gauntlets. So Reyniers has devised an arrangement whereby a man can enter the chamber without contaminating it. The attendant, one of the Notre Dame scientists, is first sealed into a flexible plastic diving suit by means of a hot jet which welds loose seams. (The design of this suit alone took three years of continual experiment.) Air is pumped into the suit and extracted through flexible tubes. Sealed in the suit, the attendant passes through an air-lock into a glass-sided cubicle. There he takes a shower-bath with detergent solution which thoroughly wets the suit in every crevice. Then, lifting a man-hole, he descends into a chamber located directly below the main drum housing the animals. This chamber is filled with strong disinfectant through which the diver must pass completely submerged before he can lift a second man-hole to enter the drum. As the attendant feeds, weighs and examines the animals he reports his findings through a microphone built into the suit.

Experiments with the germ-free animals will have to be carried out at Lobund for the time being. No other laboratory has yet built facilities for housing germ-free animals, and transporting stock between Notre Dame and other establishments would be extremely difficult.

So the Notre Dame authorities are expanding Lobund to allow scientists from other laboratories to work there. The staff already consists of six research members and forty-two technicians. There are twenty-eight laboratories and administrative buildings.

Using Lobund's germ-free animals, Chicago University scientists have recently gone far towards settling the argument as to whether bacteria cause dental decay or are merely secondary invaders of cavities caused in teeth by mouth acids. In a series of carefully controlled experiments germ-free animals did not develop tooth-decay, whereas normal animals fed on exactly the same diet did.

Experiments also seem to have proved that bacteria are not essential for digestive processes in the animals tested so far.

Studies are now being made to determine whether the bacteria normally present in the alimentary canal affect the longevity of their hosts. The Russian scientist Ilya Metchnikoff believed that the toxins set free by intestinal bacteria considerably reduced the human life-span. With germ-free animals it will now be possible to put his theory to thorough test for the first time.

Patterns in Your Head

Dr. GREY WALTER

Burden Neurological Institute.

PATTERNS interest us all, and from a very early age. My son Timothy, aged two, would introduce this business of patterns to you by pulling you down to the floor among a scrambled lot of dominoes, saying insistently: "Pattern, pattern." So you arrange the dominoes in a line, or to form a capital 'T', bringing order into his scrambled universe. The letter T is a shape he remembers, or will remember, and will compare with other shapes he already has fixed in his head.

Things with well-defined patterns are comforting things. You can *remember* them, whereas chaos or disorder escapes the memory. At a very early age the human being is a pattern-*making* animal and—the other side of our subject—he is also a pattern-*seeker*: he looks for patterns among the dominoes scattered on the floor; in much the same way our remote ancestors looked for patterns in the disorderly array of stars, and the picturesque constellations he found were the beginnings of astronomy. Indeed one may say that every science is born of the instinct for *pattern-seeking*, and perhaps every art derives from the correlated practice of pattern-making. These articles will discuss patterns found in the brain, and the making of patterns in it.

The patterns of brain activity are found by taking electro-encephalograms—'brain-prints' for short. These brain-prints are records of the natural electrical impulses which are given off all the time by the brain. There are several ways of getting them.

The simplest is to have a set of pens writing on a moving paper strip. The pens are guided by the electrical impulses from the brain, and they draw wavering lines on the paper. The patterns in the brain-prints so obtained are hard to pick out and interpret because no part of the brain does the same thing twice, and no two parts do the same thing at the same time. At present we understand only the simplest of these patterns, and there is still a great deal of discussion about what they mean. One of the first things to be noticed about brain-prints was this; the harder the brain is working, the more difficult it is to pick out the pattern of its electrical activity. This feature of brain patterns is so odd that it deserves closer examination, but we must first consider what we mean by pattern in general.

For convenience, we can divide patterns into two main groups: *patterns in time* and *patterns in space*. Perhaps the simplest example of a time pattern is a tune, and of a space pattern a picture. The loudspeaker of a radio set projects a series of patterns in time, whereas the screen of a television set projects a series of patterns in space. This illustration suggests at once how different these two kinds of patterns are. A schoolboy could make a crystal set for a few shillings, but a television receiver costs fifty pounds or so. The reason for this big difference is that the television set is much more elaborate.

But why must a television set be so much more complicated? Because the receiver has to convert a time sequence of impulses arriving from the transmitter into a pattern in space—a pattern of lines on the screen making up a visible moving picture. The lines are not quite real, being formed by a spot of light which sweeps regularly backwards and forwards over the screen.

It is this scanning device that makes a television set so complicated and expensive. Your eyes and brain have just the same problem as a television receiver has in dealing with the space patterns of things we see.

Now we can go back and try to understand a bit more about the time pattern of brain activity which is shown in brain-prints. The largest and clearest pattern in the brain-print of a normal adult is usually a rhythmic oscillation composed of about ten changes or impulses per second. These changes correspond to very small alternating currents only about one-millionth as big as you need to light a lamp. This rhythm is called the 'alpha rhythm', and the first thing we notice about it is that in most people it is biggest in the back of the head and is largest when the eyes are shut and the mind is tranquil. It is reduced by mental effort or by opening the eyes. This is illustrated by the pictures on pp. 58 and 59.

One interesting thing about these changes in the alpha rhythms is that the most important factor in bringing about a change seems to be the effort or compulsion to see or appreciate pattern. Large alpha rhythms recorded with the eyes shut do not change much if the eyes are opened to a completely featureless scene; but any pattern, or the *effort* to find such a pattern, usually blocks the rhythms. This may also happen when the eyes are open in the dark, if the subject thinks there may be, or ought to be, something to see. The duration of the impression, or effort to see, is shown by the changes in the wavering line of the brain-print, and you can tell in the same way how hard and how long a person is thinking if you give him a sum to do in his head with the eyes shut.

So seeing patterns, or looking at them, breaks up the pattern of the brain-print almost as though the alpha rhythms were looking for pattern and stopped when they found it.

To make this clearer let us consider what happens if you are looking at a scene in which all the details stay the same for a long time—a true space pattern like a landscape.

Now you may think that you can take in the whole of a static picture at one single glance, as a camera lens does, without moving your eyes, but actually you can't. The reason is a simple one: it is true that the lens of the eye is like that of a camera, but the retina which receives the image is quite unlike a photographic plate or film in one very important respect. The whole surface of a photographic film has a uniform 'grain', but there is no similar uniformity about the surface of the retina. Only a minute patch—about a third of a millimetre wide—in the centre of the retina has a grain fine enough to give a sharp picture. This patch alone contains the special light-sensitive cells or 'cones' which have their own private and individual nerve fibres leading to the brain. Around this patch are groups of cones, and also the more sensitive but less discriminating 'rods' connected together in bunches to a single common nerve fibre. This arrangement means that

the power to see detail is high in the centre of the field of vision but very poor outside it. You can test this for yourself if you open a book and fix your gaze very steadily on the centre of the page; don't move your eyes at all, and then you will find that you can only read one or two words around the point your gaze is fixed on, while the rest of the page, though perfectly visible, is indistinct and unreadable.

This is not just a matter of focus. To read the page of print you have to scan it line by line; this scanning process is indispensable owing to the fact that the angle subtended at the lens of the eye by the minute discriminatory patch in the centre of the retina is only about two degrees. In order to view a landscape which subtends, say, an angle of ninety degrees at the eye, you have to make several hundred peeps and sweeps requiring thousands of co-ordinated eye movements to scan it.

It sounds tiring, doesn't it, all that effort to take in a landscape? And from the physiological standpoint, so it is. Indeed the reproduction of such a scene reduced in size to subtend an angle of, say, ten degrees, flattened and shorn of irrelevant details, saves an enormous amount of effort of perception. It is vastly easier on the nervous system to look at a picture of the landscape than at the landscape itself. Perhaps this lessened strain has something to do with the particular pleasure we feel in looking at a painting or photograph.

Now suppose you are looking for *one particular word* on a page of print. You must scan the page line by line until you come to the word, and then the scanning movements stop. Anyone watching your eyes can tell when you find what you are looking for by noting when your eye stops moving. You can see that this is rather like what happens when the alpha rhythms are checked by doing a sum or looking at something.

The scanning by the eyes is like taking a picture with a mobile television camera. How do we put the pictures together? How do we become aware of the brain image which has been conveyed to the back of the brain by the optic nerve? Scanning by the eye has given us a pattern in space in the brain, but this image is no good to us lying at the back of the brain. We've to get it to the other parts of the brain where images are compared and recognised. I have suggested that the activity of the alpha rhythms may be the key to understanding and transference of information from the visual projection areas at the back of the brain to the association areas. Rhythmic oscillations of this kind I suggest may be essential for transforming the pattern of things seen in space into a sequence of signals in time. One bit of evidence for this theory is that if you look with your eyes closed at a bright light flashing on and off at about ten per second, you see more than just a flicker. There is always a sense of movement, and very often a chequered pattern appears, rotating and pulsating in a quite dizzy fashion. The direction of rotation and the colours in the pattern may change as the rate of flashing changes. This illusion of movement may be due to rhythmic waves of activity spreading from the brain's projection areas into the association areas. These illusory patterns are more vivid when the eyes are shut, because then there are no real patterns to interfere with the rhythmic sweep of activity that is registered in brain-prints as the alpha rhythms. This curious effect can be accounted for if we regard the flicker as interfering with the normal process of scanning. A similar effect can be produced on a television screen by illuminating the television studio with a flickering light. The resulting interference with the picture would be very hard to bear. The effect of flicker is sometimes just as confusing to the brain; the conflict between the two different time patterns—the inherent scanning rhythms of the brain, and the flicker—can produce a brainstorm as wild as any distortion on the television screen.

There is another justification for the theory that scanning takes place in the brain, and that some of its electrical patterns are connected with scanning. The transformation of a pattern in space into a pattern in time is used in television for economy's sake, because by scanning the scene hundreds of thousands of details can then be transmitted on a single cable or a single radio channel, and no separate cable or channel is needed for each individual detail. Some such economy is absolutely necessary in the brain. The number of nerve circuits must be limited by some means; there cannot be a separate nerve for each detail all along the line—otherwise the brain would have to be the size of a house!

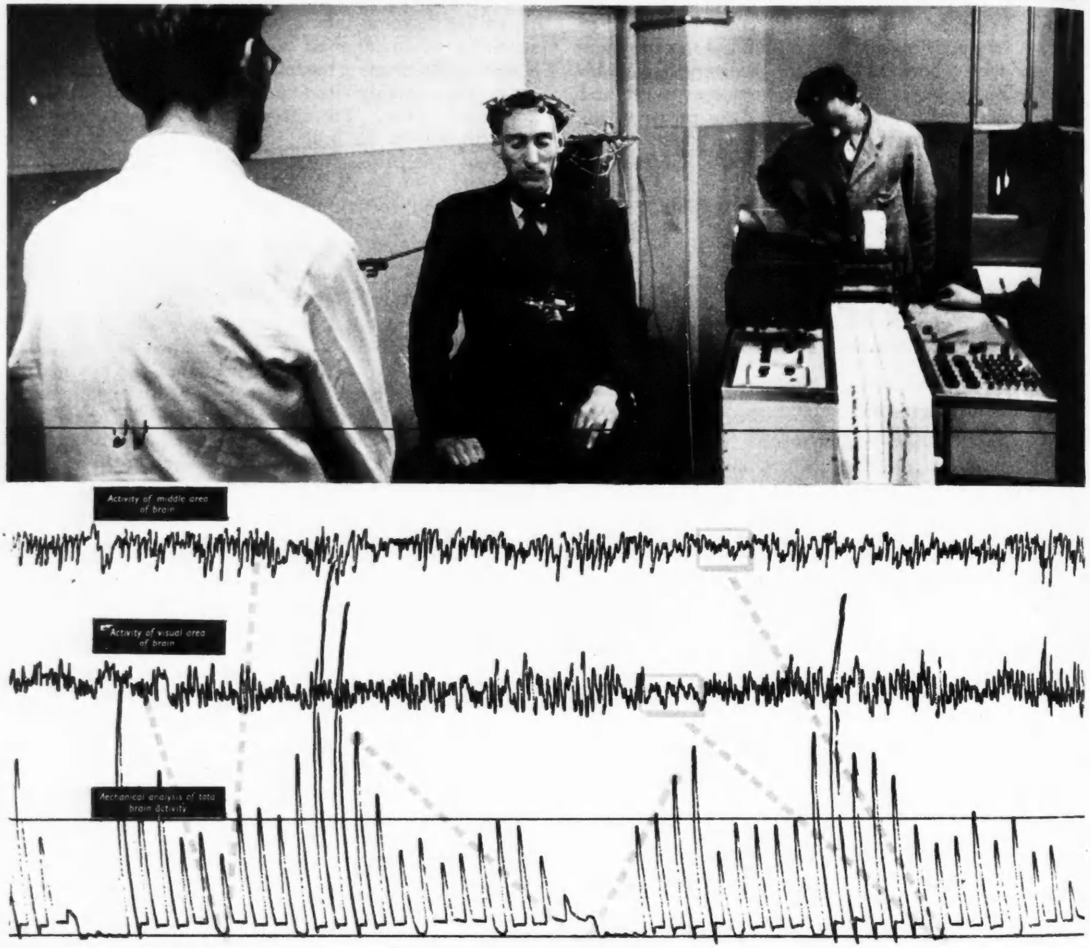
A scanning process for the most active and useful of human senses would be the first device to occur to a competent engineer who set out to design a portable brain. Of course a scanning system has its disadvantages. For the perception of a pattern takes time—about one-tenth of a second is needed to recognise a visual pattern. You will recall that a tenth of a second is also the normal period of the alpha rhythms, and this coincidence favours the scanning theory. You can roughly measure this reaction time by finding how many words you can read in ten seconds; the total will be about one hundred, in other words, one for each tenth of a second. Another disadvantage is that if any change occurs which affects what you are looking at during the scanning interval it will produce a visual illusion; thus when one lamp is switched off just before another is switched on, it looks as if there were a movement of the light from the first lamp to the second. But these drawbacks were of minor importance in the struggle for existence. What mattered most to us was that we could see and recognise and remember the pattern of events better than any other animal could.

From simple animals, through monkeys and apes to Man, the size of the association areas has increased steadily during evolution. We have learnt to master the world by recognising, remembering and comparing patterns more efficiently than other animals. Our brain has developed as a pattern-seeking and pattern-making instrument with its own supreme complexity of pattern; it is an instrument infinitely more wonderful than television, more wonderful indeed than any of its own creations. With our great capacity for recognising patterns goes the greater power of learning by association.

Learning involves changes in brain patterns, and these changes are not very simple. I have already mentioned that thought tends to break up some of the patterns shown in brain-prints, particularly the alpha rhythms corresponding to the rhythmic changes in voltage which appear when the brain is resting.

The brain patterns become even less orderly when the brain is learning. This is consistent with the concept that

THE ENCEPHALOGRAM SHOWS HOW THE PATTERNS IN THE BRAIN OF A PHOTOGRAPHER



The photographer sits and waits with eyes shut before the encephalogram. Electrodes on the mid and rear parts of his brain record the normal 'alpha' rhythm of a brain at rest.

The large strokes show (by electronic analysis) the real rhythm of the brain's electrical activity.

The photographer thinks hard about the photograph he is to take. The alpha waves are interrupted by smaller, slower ones and the analysis reflects the change seconds later.

it is hard to remember disorder, and learning involves finding coherence in a great mass of apparently unrelated and uncoordinated impressions. This makes the subject difficult, but I shall try a new approach to this problem by way of an electrical model of learning that I have made, which should simplify the matter.

The animal that cannot learn by experience how to get its food, how to avoid or overcome repeated dangers cannot survive. Many prehistoric monsters disappeared from the earth for this reason. Physically their structure was magnificent, but their nervous system had developed only in the lower centres; and the *lower* centres cannot deal with uncertainty, cannot reckon the odds, and reckoning the odds is a function of the higher centres; indeed I think it is their principal function in learning. Now we want to be clear about what ways of learning there are to discuss.

There seem to be two main ways of learning: these are *learning by association* and *learning by habituation*. These are nearly always connected, of course, but we must distinguish between them very clearly.

Learning by habituation I shall dismiss quite briefly. It involves merely the repetition of something we've learned by association, doing it over and over again and doing it better every time, like perfecting your typing when once you have learnt by association where the keys are. Practice makes perfect, as the saying goes. My only other point here is that improvement by repetition is seen in very simple animals and even quite simple machines. We do not have to picture any exceptionally elaborate brain mechanism to account for it.

But something very different happens in the brain when it learns by association; when, for instance, a baby begins

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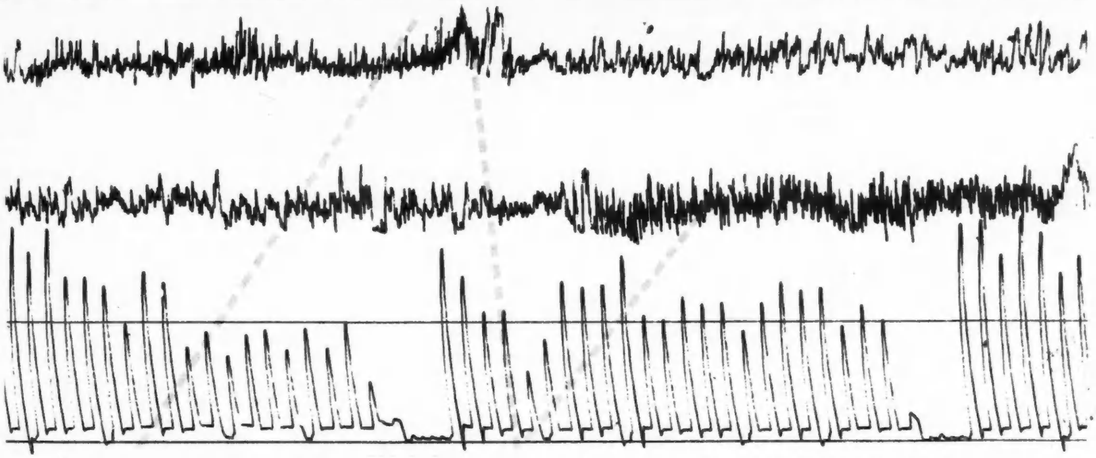

The two jerks on the top line of the picture record the passage of time; ten seconds between each set of two jerks.

The photographer takes a photograph. The pens write more hurriedly as other areas of the brain come into action and affect the areas from which the recordings are taken. The record shows this greater activity in terms of greater electrical disturbance—and his muscular movements also affect the graphs.

Photographs by courtesy of "Picture Post".

to associate a certain word with a certain object, the first stage towards making a sound that is more than a cry. Learning of this sort, like habituation, depends upon repetition; but here we have the repetition of *two events* outside the baby—the appearance of the object, and the sound of the word. The significant thing is that the two events must happen regularly and frequently, and more or less together. That is, the word and the object must not just come together occasionally by chance, or so far apart in time or space that the pattern of their association is obscure.

Study of these patterns of association was the life-work of the great Russian physiologist Pavlov; he invented an experiment in which the effect of association could be measured. He measured the amount of saliva produced when a dog's mouth watered on being given food. Then he found that if he regularly rang a bell whenever he gave the food, after twenty or so repetitions, the dog's mouth started to water as soon as it heard the bell, even before the food appeared; and the amount of saliva could be measured and compared with the normal effect produced by giving food. We say that the salivation reflex had been conditioned.

The measurement of conditioned reflexes was an important step in our understanding of the activities of the higher centre of the brain, but the knowledge which it gives of them alone is limited in much the same way as if Harvey had discovered the circulation of the blood without asking how it circulates, and how it is made to circulate.

Pavlov did not live to carry his work beyond that point, and unfortunately his Russian disciples seem content to follow him to the grave of research, repeating his experiments every day without ever, so far as one can learn,

asking themselves *how* it happens—how the animal decides that the new signal, the ringing of the bell, is significant.

How, then, does the brain decide that two particular signals are significantly associated? How does it decide that the pattern made by this pair, among all those that it is receiving, has some special significance?

In approaching this problem anew, I found that it was clarified for me by thinking of the brain centres as a generalised transmission system of unknown properties—by that I mean, as a sort of Black Box into which signals go and from which other signals come out. You may not know what goes on inside the Box, but you can check what goes in and what comes out, and by comparing the input and the output you can get some idea of what is happening inside. This method of assessing the value of incoming and outgoing signals is familiar to radio and telephone engineers, who have to discover how signals can best be distinguished from background noise, the distinguishable signal being in fact the significant event or pattern we are discussing.

The advantage of this method of looking at the brain is that we can use familiar and powerful statistical means of working out the simplest way of distinguishing important pairs of signals from random or meaningless ones. We can then consider in greater detail the conditions in which two signals have a significant effect, and so get a still clearer idea of what goes on in the Black Box.

Study of conditioned reflexes has shown that, for an association to be effective, the neutral signal, such as ringing the bell, must always be either simultaneous with or precede the specific signal, that is, the food. This is like saying that it is no good ringing the dinner-bell after dinner. If the neutral signal appears a long time before the specific signal—that is, if the bell is rung, say, half an hour before the food is given—the association must be repeated much oftener than if the two are simultaneous. The next thing to note is that if, after the association has been established, the coincidence never happens again, then the memory of the association will fade away; and it will be forgotten even more quickly if for some reason the neutral signal, the bell, appears without being followed by the specific one, the food.

One begins to realise that inside our Black Box there must be something that sorts out pairs of associated signals or patterns and gives them special significance *if* they always happen in the same order. In everyday terms, the brain decides that, if one thing happens after another pretty regularly, the first thing *means* the second.

Thus we can learn something about the working of the brain, simply by checking signals going into this Black Box against those coming out from it, and get a general picture of what must go on inside. The next step is to analyse this learning process. Above all, it becomes possible for us to find out the least number of stages necessary for the process, necessary for dealing with the assembly of incoming signals, for picking out the important ones, and holding the memory of their importance long enough to allow effective action to be taken. My conclusion was that, in order to deal with incoming signals like the Black Box deals with them, the brain has to put the signals through just seven different stages—*four stages* of statistical sorting and reckoning the odds, *two stages* of storage (i.e. memory), and *one stage* of action.

After many experiments with electronic circuits, I worked out a system which does perform these seven functions. In effect this means that a machine has been made which behaves very like a Pavlov dog. It is a machine that can be trained to associate one set of signals with another and learns to respond to them like the dog learns to respond to the ringing of the bell as if it were food. We have, then, a machine that really learns. It has a pet name—CORA, which is short for Conditioned Reflex Analogue. Some of you may have seen in the Festival of Britain Exhibition at the Science Museum an early model of an imitation animal, which prowls about looking for lights. This was called ELMER for Electro-mechanical Robot. ELMER has no Black Box like this and was unable to *learn*. We could have combined the two machines but their behaviour would have been too complicated to have taught us much.

Now let me describe to you quite simply how CORA works, by taking a single instance of its operation. She—CORA—is about the size of a portable radio set, and has two buttons on her; let's call them *A* and *B*. Press button *A*, and nothing happens. Press button *B*, and a light shows. *A* is like ringing the bell; *B* is like the food: the light is the response to the food, that is to say the salivation of a Pavlov dog. But, now, if on the machine you press button *A* and button *B* one after the other a dozen times or so, *A* always just before *B*, an indicator will ultimately show when the two signals are associated in the machine's electrical memory; *then* if you press button *A* alone, the light will come on just as if you had pressed button *B* as well. In other words the reflex has been conditioned. But of course if you go on pressing button *A* by itself a number of times, presently the response to *A* will fade and fail; meaning that the memory of its association with *B* has lapsed.

The memory device is worked by an oscillating circuit. This circuit is so arranged that oscillations begin only when the coincidence of close sequence of the two signals, *A* and *B*, over a given period, has occurred *more often* than if the signals were random or disorderly; that is, were without an associational pattern. The clearer and simpler the pattern of association, the more quickly its importance can be recognised.

The value of this model is not limited to the imitation of this simplest example of a conditioned reflex; it copies quite a number of the important details of the learning process; for instance, when the pattern of association becomes too confusing, it may have a sort of nervous breakdown.

But the fact that the model does these things with the smallest possible number of components and the greatest possible economy is the most important thing about it. And for this reason. I mentioned above that great economy in its mechanism is an essential character of the brain. Now, if my neighbour and I both have to be economical, we probably pay the *same price* for what we buy—the *lowest* price. As this model obtains patterns of association—in other words, patterns acquired by learning—at the lowest mechanical price, the simplest theory of learning is that the learning mechanisms in the brain are similar to those in the model.

Perhaps the ever-changing patterns of electrical rhythm which we find in brain-prints are related to the patterns of

learning, which all the time are trying to reckon the odds in favour of what we experience being important.

There is one man I should particularly have liked to show this model to. His name is Dr. David Hartley. He was the first man to suggest that "association of ideas" might depend on vibrations in the brain, still a novel and difficult notion. But Dr. Hartley picked his runner at long odds more than *two hundred* years ago, an outsider well up in front today in the long race of physiological research.

Patterns of Personality

So far I have spoken as though all brain patterns were the same in everybody, but now we come to the consideration of some of the differences which exist between individual brains and which seem to reflect differences of personality.

By personality I mean something more than just identification of one person as different from all other persons. A finger-print will do that; so will a brain-print. But that is where resemblance between the two ceases. A finger-print is a unique personal pattern that never changes. A brain-print is unique and personal too, but it is not static; it is changing all the time. A brain-print is recognisable in the same sort of way as you recognise an individual face throughout all the changes of expression that transfigure it from moment to moment. Indeed, one of the first things noted about the alpha brain rhythms was that in no two people are they the same. The alpha patterns are not identical even in identical twins. But for one particular person, the features of the pattern remain remarkably constant from year to year, once that person has reached maturity, at the age of fourteen or so. Between individuals the alpha patterns vary widely, and this variation proved as difficult to analyse as the variation of lines in a finger-print had done originally. But with time, ways were found of classifying these variations; it was discovered, for example, that the changes in alpha rhythms produced by patterns of thought or outside signals could be classified into three main groups.

It was found that in most people the alpha rhythms (which are prominent when the eyes are shut and the mind is at rest) disappear whenever the eyes are opened—or when the subject thinks hard, as, for example, while he is doing a sum in mental arithmetic. That is the first group, called "*R*"—the "*R*" stands for *responsive*.

The second group contains those whose alpha rhythms continue even when the eyes are open and the mind is alert. This is a smaller group, and it is called "*P*"—for *persistent*.

The third group contains people whose brain-prints show no significant alpha rhythms even when the eyes are shut and the mind blank. This is the "*M*" group—"*M*" stands for *minus*. People in this group think almost entirely in terms of visual imagery.

You may be able to decide which group you belong to by the following simple test: Shut your eyes. Think of a cube with all of its six faces painted. Now imagine that you cut it in half across the middle of one face; repeat the process with a cut at right angles to the first, and then make a third cut so that you get eight little cubes of equal size.

Think of the eight cubes you now have. How many of their sides are unpainted? The answer is, of course, twenty-four.

But what else did you see? What colour was the original large cube? What was it made of? Did you see sawdust falling as you cut it? Did you solve my first question by arithmetic? If your picture had more details than are essential for its solution, you are probably a visualist with few alpha rhythms; if you could not get any picture at all you are more likely to be a non-visualist with persistent alpha activity. If you had a picture that was just clear enough to enable you to answer that question, but no more, then you are probably a mixed type with a responsive alpha rhythm.

When a solution or decision of any kind can be reached by visualising it, the performance of the "*M*" type of person is rapid and precise, but when he is faced with a problem of an abstract kind (or one in which the mental pictures have to be too elaborate) he becomes sluggish and confused. At the other extreme is the small "*P*" group of people, whose alpha rhythms persist even with the eyes open and the mind concentrated on a sum; a person in this group does not use visual images in his thinking unless visualisation is indispensable to the thought, and even then his mind's eye is almost blind; he thinks in abstract terms or in sounds or movements. This kind of person may even have to *feel* his way out of an imaginary maze in sharp contrast to those of the "*M*" type. The "*R*" group, whose alpha rhythms disappear when they do a sum or open their eyes, are intermediate between the other two; while they do not habitually use private picture shows for their everyday thinking, they can evoke satisfactory visual patterns when necessary, and they can combine data from the various sense organs more readily than can either the "*M*" or "*P*" types. So even if you visualised the cube just now, it is possible that you belong to the more adaptable and versatile "*R*" group; only a study of your brain-print could decide that.

There is still a great deal to learn about these three groups. But data already collected strongly suggest that the alpha characters are inborn and are probably inherited. In any case, our brain-prints show that many of the differences of character which are commonly recognised in everyday life are firmly rooted in the patterns of brain activity. These differences of character are part of the charm of our daily life. But what a lot of unpleasantness can be caused by them! "I just can't get on with him", you say, or "we don't see eye to eye, simply don't speak the same language". Has the growing scientific knowledge of how the brain works anything to say in explanation of this common trouble, anything to suggest for making personal relations and social relations smoother?

Consider again the three types of people. The classification I have sketched above corresponds to three different ways of thinking, three different ways of dealing with a particular question. If the question involves a simple arithmetical sum it does not matter how the problem is solved; the correctness of the final answer can be checked immediately, and no discussion of the method used to arrive at it need arise. But if the problem is one of personal relations—and such problems arise by the hundred in our daily lives—discussion of the problem can lead to a wrangle long before we come near the point of agreement.

Supposing Peter and Mary are looking through their mail at breakfast and find an invitation to a party, which means they will have to decide whether they want to go to it. Let us suppose Peter is an extreme "*P*" type, while Mary is an extreme "*M*" type. What happens? Mary will have a vivid mental picture of the whole thing: she will see her new dress, their journey to the party, the party itself, the people they will meet, and so forth; that is the way "*M*" types think, and Mary will reach her decision in that way, and will attempt to make Peter see it in that way too. But Peter, being a type who does not use visual images in that easy way, but thinks more in abstract terms, will consider the rights and wrongs of the case, striking a balance between such things as duty and pleasure, conveniences and effort, in his own way. He will be irritated by Mary's efforts to make him see her mental pictures, while she will be equally annoyed by his attempts to make her appreciate his heart-felt abstractions. Worse than not speaking the same language, their mental accents, so to say, are incompatible, and neither will give the other credit for clarity, consistency, or good taste. The fundamental differences do not arise because Mary is a woman and Peter a man; the situation might quite well be reversed, with Peter being a visual type and Mary an abstract thinker. The big differences are connected with the fact that one is an "*M*" type and the other a "*P*" type.

Fortunately such extreme types are rare, but if two people simply cannot get on together it might be worth finding out whether they have different ways of thinking.

How many of our international negotiations may be frustrated simply by the fact that one of the negotiators is an extreme "*P*" type and the other an extreme "*M*" type!

Let us take this sort of situation a stage further. Suppose that Peter and Mary carry their wrangle to the stage when they begin to stamp and scream and break things. How childish, we should say! And that's just what it is, when grown-ups lose their temper—childish. For then an entirely new pattern appears in their heads, a pattern which is actually very common in children; indeed it is characteristic of children. This leads me into another field of study. When my wife and I first explored this field it was quite uncharted. We soon discovered a curious phenomenon; there is another kind of electrical pattern in the brain of children up to the age of ten or twelve. This rhythm—known as the *theta rhythm*—comes from the middle of the brain, and has six cycles a second. The theta rhythm does not change much with visual patterns, but is associated in some subtle fashion with your feelings. It is seen most clearly in a young child who has been *frustrated*, say, by having a proffered sweet snatched away. In older children the effect is more apparent in the experience or memory of humiliation or in an access of anger. In *ordinary* circumstances the theta rhythm is scarcely visible in good-tempered adults, but in many adults any simple frustration can evoke it; for example, the sudden *interruption* of a prolonged *pleasant* stimulus, such as stroking the head. A really disagreeable stimulus will do it too, but it is much harder to arrange for such a stimulus in a laboratory where such an attempt is obviously artificial; it is necessary that the subject must be made to feel deeply offended by some personal affront, and this is difficult to organise under the conditions of a laboratory experiment.

But in bad-tempered people, especially those with an abnormal tendency to aggressive behaviour (sometimes labelled psychopaths), the theta rhythms are often prominent and may occupy quite a large area of the brain. Their childish intolerance, impatience, suspicion and selfishness are reflected in the juvenile appearance of their brain patterns. Are they still children at heart? Perhaps the theta rhythms may be regarded as scanning-for-pleasure patterns, in the same sense as the alpha rhythms scan for visual patterns. This means that just as people with persistent alpha rhythms cannot imagine visual pattern, so bad-tempered people with persistent theta rhythms simply cannot imagine or anticipate happiness.

By watching the growth or decline of theta rhythms in a child, we can follow, to some extent, the growth of personality. In particular we can watch the development of what is usually called self-control. When a person who normally shows no theta rhythms looks at a large bright light flickering at about six per second (i.e. at the theta frequency) a theta rhythm may appear in his brain-print, and if this happens he experiences a sensation of bad-temper. If he gives way to his feelings, the theta pattern will increase, but if he tries to keep his temper, the pattern fades away, and so too does the feeling of annoyance. This effect varies with the mood of the subject, but on the whole it increases with maturity, as we should expect it to.

To the limited extent I have indicated, we are thus able to trace a material basis for certain features of personality by studying the effect of a stimulus on the electrical patterns of brain activity. In a limited but progressive degree we can watch the differentiation of patterns which accompanies our maturing differences of personality. But, as the prospect widens, and our respect and wonder grow, pride and confidence must wane. For the brain, as a statistical predictor, makes few assumptions about what can and what cannot happen; from its first experience of birth it provides for the implication of almost any phenomenon by almost any other. This fact we know simply by the vast capacity for learning which we possess; a man may learn by experience to associate two series of events between which any connexion at first seemed wildly improbable. To do this, every single signal entering the nervous system must be relayed to every part—though not necessarily to every cell —and not merely, as was thought at one time, to the specialised receiving zone.

Thus from the knot of an event is generated a web of speculation; when two series of events are perceived together they form warp and woof of a shimmering fabric into which are woven the patterns of thought, of learning, and of personality.

Far and Near

Night Sky in February

The Moon.—Full moon occurs on Feb. 11d 00h 28 m, U.T., and new moon on Feb. 25d 09h 16m. The following conjunctions with the moon take place:

February			
15d 14h	Saturn in conjunction with the moon	Saturn	7° N.
17d 15h	Mars ,,	Mars	7° N.
23d 03h	Venus ,,	Venus	3° N.
28d 08h	Jupiter ,,	Jupiter	5° S.

The Planets.—Mercury is a morning star early in February and rises about the same time throughout the month—7h 20m—but is too close to the sun to be seen at any time, even when it is an evening star later in the month. The planet is in superior conjunction with the sun on Feb. 22. Venus, a morning star, rises shortly before 6h throughout February, and can be seen in the eastern sky, the stellar magnitude varying between $-0{\cdot}3$ and $-1{\cdot}3$. Nearly all the visible portion of the illuminated disk is visible towards the end of the month, which accounts for the increased brightness of the planet in spite of the fact that its distance from the earth on Feb. 29 is 130 million miles compared with 115 million miles on Feb. 1. The close approach of the planet to the moon on the morning of Feb. 24 has been referred to under conjunctions. Mars is a morning star, rising half an hour after midnight on Feb. 1, and half an hour before midnight towards the end of the month. About Feb. 24 and for a few nights afterwards the planet is a little N. of the star α Librae. Jupiter is conspicuous throughout the early portion of the night, its times of setting at the beginning, middle, and end of the month, respectively, being 22h 10m, 21h 35m, and 20h 55m. Saturn rises at 22h 35m on Feb. 1, and 20h 40m on Feb. 29, and is easily recognised about 7° N. of the bright star α Virginis, generally known as Spica.

On Feb. 10 there is a partial eclipse of the moon, visible at Greenwich. The moon enters the penumbra on Feb. 10d 22h 06·2 m, and the umbra on Feb. 11d 00h 03·3m, that is just after midnight of Feb. 10, and leaves the umbra on Feb. 11d 01h 15·3m. The eclipse is not very conspicuous as less than one-tenth of the moon's disk is in the shadow cast by the earth which then interposes between the sun and the moon.

There will be a total eclipse of the sun on Feb. 25, but it is visible only as a partial eclipse in the British Isles; at Greenwich just over one-tenth of the sun's disk appears in the shadow cast by the moon which is then between the earth and the sun. At Greenwich the eclipse begins at 8h 42m and ends at 9h 47m. A British expedition is going to Khartoum where the eclipse is total. The eclipse totality line runs near the equator, from about midway between the coasts of South America and Africa, touching the latter at Libreville and then, turning towards the north-east, it passes over Bangui, Khartoum, Basra, Khiva and Semipalatinsk, soon after which the eclipse ends.

Uranium Search in Sierra Leone and Gold Coast

On New Year's Day a British expedition left Freetown on a geological exploration of Sierra Leone and the Gold Coast. The expedition is searching for deposits of uranium and thorium, which are required for the British atomic energy project. This will be the first geological survey to be made of jungle and bush country there.

The expedition is using a new type of Geiger-counter detecting equipment, mounted in Land Rover vehicles, and this will automatically record the presence of radioactive elements in the subsoil of the country through which it is driven, and indicate whether an individual deposit is a significant one. Minute amounts of uranium and thorium are present in all rocks and soils, the content varying with the type of geological formation. As the new instrument is capable of revealing variations in the amount of radioactive material as it moves from one spot to the next, it is expected to become a useful tool for making geological maps, as it should be able to distinguish different kinds of rock, providing these have different radioactivities. Workable uranium deposits would be readily discovered by means of this technique.

The party is being led by Mr. Dennis Ostle, of the British Geological Survey. He is being accompanied by Mr. F. H. Hale, an expert on Geiger-counters of the Atomic Energy Research Establishment. Officers of the Sierra Leone and Gold Coast Geological Surveys are collaborating in the search.

The detecting is described by the Ministry of Supply as "consisting of eight tubes, each about 2 ft. 6 in. long, with an automatic recording mechanism with an additional buzzer 'alarm' system should a strong deposit be found".

Russians quote British Scientists' Ideas on Atomic Control

Recent Russian newspaper and magazine articles have been giving a great deal of space to criticisms of official British and American proposals for atomic control. An example is the article by A. Sverdlin, originally published in Russia in *News No. 8* and reprinted by the Russian Embassy's London journal, *Soviet News*. According to him, "A memorandum, published in 1947 by the British Atomic Scientists' Association, which included Rudolf Peierls, Philip Moon, M. L. E. Oliphant and other eminent scientists, rightly pointed out that to give the 'international control agency' rights of ownership of atomic energy plants 'would cause complications, since it would give the energy control agency the right to decide whether any particular country may build energy plants, and to prevent any country from using the energy produced by such plants or to lay down conditions for the supply of such energy'. And the British scientists stressed that 'such restrictions would give the possibility of interference in the economic life of each country to a degree not essential to the purpose of preventing the abuse of atomic energy for destructive purposes'. What system of international control is required and the principles on which it should be based to ensure real and effective control, giving the maximum guarantee that atomic energy is not used for non-peaceful purposes, is a problem of the utmost importance to mankind and must be solved with the least possible delay." The article is headed: "Atomic Control—The Facts", but does not quote the views of other British scientists on this subject, and hence conveys the impression that the A.S.A. memorandum had the support, and continues to have the support, of British experts on atomic matters.

A British Flora of Algae

Prof. F. E. Fritsch and Dr. J. W. G. Lund are preparing a Freshwater Algal Flora of the British Isles. They would be glad to hear of any unpublished records or of records published in the proceedings of local natural history societies. If the record relates to a rare species or to one new for the British Isles, they would be obliged if material could be sent to Dr. J. W. G. Lund, The Ferry House, Far Sawrey, Ambleside, Westmorland.

A 175-year-old Tortoise

One of the oldest animals alive today is mentioned in the Colonial Office book called *Introducing the British Pacific Islands* (H.M.S.O., 2*s.* 6*d.*). It is a tortoise which was shown to Captain Cook in 1777 by a Tongan chief, and which still lives in the grounds of Queen Salote's palace at Nuku'alofa, Tonga. Survivor of a lorry accident and a bush fire, it still receives the customary presentations of food at important festivals. The natives call it Tu'i Malila. The book contains many interesting facts about the Fiji Islands, one of the world's greatest coral regions, where the reefs extend for hundreds of miles and some of them continue their upward growth at the rate of 1½ inches a year.

The International Pharmacopoea

The first volume of the first international pharmacopoea ever published has just appeared. Entitled *Pharmacopoea Internationalis*, it is available in English, French and Spanish. The first draft was started in 1937, under the auspices of the League of Nations Health Organisation. This work was interrupted by the war, and was not resumed until 1947. The book has been compiled by experts from many countries, and is published by the World Health Organisation, Palais des Nations, Geneva. Copies cost 35*s*. each.

It should be of immense practical importance to all concerned with the

FESTIVAL HONOURS

The New Year Honours List included the names of 107 people who were connected with The Festival of Britain.

IAN COX (left) *the Festival's Director of Science, was awarded a C.B.E.* RALPH TUBBS (right), *architect of the Dome of Discovery, gained an O.B.E.*

prescribing and dispensing of pharmaceutical preparations. It is also anticipated that it will prove to be particularly useful in those countries whose national pharmacopoeas need revision. In countries which have yet to develop a national pharmacopoea, it is hoped that the authorities will adopt the *Pharmacopoea Internationalis* as a whole as their official pharmacopoea, perhaps with a special supplement being added to cover local requirements.

Volume I, in addition to 199 monographs giving specifications for drugs and preparations, contains many appendices in which reagents, test solutions, solutions used for volumetric analysis are defined, and methods of biological assay described, etc.

High-level Scientific Talks in Australia

HEADS of Government scientific research organisations in British Commonwealth countries are conferring in Australia this month. This British Commonwealth Scientific Official Conference is the first of its kind to be held outside the United Kingdom. Leaders in the fields of industrial, agricultural and medical research will attend, and will plan collaboration in civil scientific work. The conference is due to open in Canberra on February 18, and to close in Melbourne on March 7.

African Bureau to Study Epidemic Diseases of Animals

THE Colonial Office announces that Mr. W. G. Beaton, retiring Director of Nigeria's Veterinary Service, has been made director of the Inter-African Bureau of Epizootic Diseases to be set up in Kenya on the site of the East African Veterinary Research Organisation at Mugaga, near Nairobi. This bureau, which will be dealing with epidemic diseases of animals (e.g. rinderpest), has been established under the auspices of the Commission for Technical Co-operation in Africa South of the Sahara.

Mr. William Gaudenz Beaton was born in 1900, and studied at the Royal Veterinary College, Edinburgh. He entered the Colonial Veterinary Service as a veterinary officer in 1925, and all his career has been spent in Nigeria. He was appointed director of Nigeria's Veterinary Service in 1948. He represented Nigeria at the Anglo-French colonial veterinary conference held at Dakar in 1946. He is an authority on rinderpest.

Scientists for Civil Defence

THE Home Office has set up a panel of scientists to advise on scientific problems of Civil Defence. In peacetime the panel will assist in the study of the scientific and technical aspects of national planning of civil defence, while also advising the principal officers and local authorities in their respective regions. In the event of war, their positions would be similar to those of senior gas advisers in the 1939–45 War, but their responsibilities would be wider, including the hazards of atomic, biological and chemical warfare. So far all the persons appointed to the panel are chemists or physicists.

The senior scientific advisers so far appointed include: South Western Region (Bristol), Professor W. E. Garner, F.R.S.; Midland Region (Birmingham), Professor H. W. Melville, F.R.S.; London Region, Sir Charles Ellis, F.R.S.; North Midland Region (Nottingham), Professor L. F. Bates, F.R.S.; Northern Region (Newcastle), Professor W. E. Curtis, F.R.S.; North-Eastern Region (Leeds), Professor F. W. Spiers.

Antidote for Beryllium Poisoning

ONE of the hazards connected with atomic energy developments is the risk of poisoning by the metal beryllium. The search for an effective antidote to this has been proceeding for many months, and now the Argonne National Laboratory, Chicago, has announced that aurin tricarboxylic acid (or ATA) seems to offer promise in this connexion. This chemical combines with beryllium salts by a similar reaction to that of dye fixation by metallic salts. In this case, the resultant co-ordination compound is a non-toxic substance. According to *The Chemical Age* (Jan. 5, 1952), ATA has proved to be an excellent antidote in laboratory cases of animal poisoning with beryllium, cases in which the amount of beryllium given would otherwise have been fatal. If ATA proves to be a satisfactory antidote to beryllium toxicity with humans, the use of this metal in atomic-pile construction will become more likely. The serious hazards associated with beryllium were early recognised by the manufacturers of fluorescent lamps, who were forced to drop the use of luminescent compounds containing beryllium.

New Drug Offered to Scientists by Armour Chemists

A RARE CHEMICAL, so costly that it can only be given away, not sold, is offered to scientists in the hope that someone will find out what it does and whether it has any potential use as a drug. The new material, the co-enzyme known in laboratory shorthand as TPN and chemically as triphosphopyridinenucleotide, was included in the scientific exhibit shown to the Philadelphia meeting of the American Association for the Advancement of Science by the research division of Armour and Company of Chicago. (It is estimated that it would cost about $800 a gramme.)

TPN is extracted from liver by a complex and difficult process which yields only a few milligrams from a hundred pounds of raw material. Little of it has been extracted because there is almost no demand for it.

Any competent scientist who has some hopeful ideas about it may get some from Armour, while the supply lasts, in quantities of 50 to 100 micrograms. These quantities correspond to the quantity of ink used in printing the name 'triphosphopyridinenucleotide' in small letters! But microscopic as they are, such amounts are still biologically potent.

According to Lawrence L. Lachat of Armour, TPN is a co-enzyme (a substance necessary to permit an enzyme to function in the body). It contains nicotinic acid, the anti-pellagra vitamin, and may be the active form of the vitamin in the body; hence it may be essential to health and to life itself. It was discovered several years ago, but until recently there has never been enough of it for adequate investigation.

Almost equally rare and costly is carboxypeptidase, a material extracted with difficulty from the pancreas. This is priced at about \$460 a gramme. A 200-pound mass of pancreatic tissue will yield only a few milligrams of it and to date no one has yet learned what its function is in the body.

Ribonuclease, an enzyme which acts on ribonucleic acid in the genes of cells and may have something to do with heredity, sells for \$175 a gramme.

Personal Notes

DR. IRA M. FREEMAN, after completing a fifteen months' assignment as Programme Specialist in the Department of Natural Sciences of Unesco in Paris, is returning this autumn to resume his duties as Associate Professor of Physics at Rutgers University, New Brunswick, New Jersey. His post at Unesco has been filled by E. M. FRIEDWALD.

* * *

DR. O. H. FRANKEL has been appointed Chief of the Division of Plant Industry in Canberra, of the Commonwealth Scientific and Industrial Research Organisation—the C.S.I.R.O. Dr. Frankel comes to this post from the New Zealand D.S.I.R., where he has been director of the Crop Research Division. He holds the degrees of Doctor of Agriculture (Berlin), and Master of Agricultural Science and Doctor of Science (University of New Zealand). A British subject by naturalisation, Dr. Frankel was born in Vienna in 1900. He served with the New Zealand territorial forces during the Second World War.

Dr. Frankel and his co-workers at the Wheat Research Institute have accomplished the difficult task of breeding wheats which are suited to the unfavourable New Zealand environment and which yet combine the desirable properties of high yield and high quality. They have enabled N.Z. farmers to grow premium wheats suitable for high-quality bread-making, whereas previously their wheats produced only low-grade biscuit flour.

Civil Service Science

THE serious lack of applicants for vacancies in the Patent Office is given prominence in the annual report of the Institution of Professional Civil Servants, the organisation that represents Civil Service scientists and technologists. At the end of 1949, 30 vacancies for Assistant Examiners were advertised; candidates were required to possess an honours degree, but the starting pay was only £330. Only 18 applications were received, and only 3 of the 30 vacancies were filled. During the

LOUIS BRAILLE (1809–52), *who invented the well-known system of printing for the Blind. Blind himself from the age of three, he introduced Braille into a Paris school in 1829. In 1871 it was officially adopted in Britain. Braille books, published here in 1951, included such volumes as Gray's* Anatomy, *T. S. Eliot's* Collected Poems *and Ashhurst's* Physics. *(Courtesy, National Institute for the Blind.)*

latter part of 1950 a further competition was held to fill 34 vacancies. Only 19 applications were received, and only 9 candidates were interviewed. Of this number 7 were appointed, thus leaving 27 vacancies. The effect of the failure to grant proper salaries for this staff is seriously impairing the efficiency of the Patent Office. The Institution has had informal discussions with the Board of Trade, and a statement from that department is awaited.

Another paragraph in the I.P.C.S. report deals with cartographic staffs, about which an Interdepartmental Committee under the chairmanship of Mr. G. A. Brown (parliamentary secretary to the Ministry of Agriculture) has produced a report that the I.P.C.S. considers to be "a most disappointing document". The I.P.C.S. says that it was clear that the military interests in the Committee had dominated the proceedings. "In the result, officers in the Ordnance Survey Department find that virtually all the higher ranking posts are reserved for military officers. This is a fatal type of organisation, killing, as it must, all reasonable ambition. Any officer in the Ordnance Survey Department wishing to make real progress in his profession must seek transfer out of the department at the earliest possible moment. The Institution made a number of efforts to see the Minister in order to discuss this, but was met with a blank refusal. The Institution will utilise every opportunity to alter the present unsatisfactory state of affairs."

Aureomycin and Infantile Paralysis

CHICAGO.—Aureomycin, one of the new antibiotic drugs, should be carefully tested in a long series of cases of infantile paralysis because preliminary tests indicate a probable beneficial influence on the disease. It is known that the average duration of the fever period of the disease was only 2·3 days in patients who received two grammes or more of the drug per day; average duration of the fever period without aureomycin was 4·8 days. No claim is made that aureomycin is the answer to infantile paralysis, but it has apparently some power to influence the course of the disease.

Blowflies and Slaughterhouses: Prevention of Infestation

SUCCESSFUL experiments to prevent blowflies breeding in slaughterhouses have been carried out by the Pest Infestation Laboratory, D.S.I.R.

This problem of blowfly infestation is one which has caused concern for some time for, in addition to causing food wastage, blowflies carry diseases. The refuse in slaughterhouses is an ideal food for blowfly larvae and, in one experiment, over 75,000 maggots emerged from 45 lb. of refuse exposed to blowfly attack for only eight hours. A ton of refuse is, therefore, a potential breeding ground for nearly four million blowflies, and many slaughterhouses produce more than that amount a day. The blowflies are not only bred on the premises but are also attracted from other breeding grounds, such as refuse disposal depots and the yards of butchers' shops and restaurants.

Most of the blowflies were found just outside the slaughtering rooms. They do not normally settle on the inside of a building unless it is brightly lit by direct sunlight. They enter the room by following a shaft of sunlight through an open doorway or window and after settling on the meat leave in the same way. 5% DDT dust was applied regularly to the refuse heaps and nearby vegetation where most of the flies could be expected to come into contact with it. During the past two years this treatment, combined with systematic rotational storage and collection of refuse, has prevented all breeding of blowflies on the slaughterhouse premises.

Various other treatments were used and over 80,000 blowflies from the treated refuse heaps were examined to discover what the effects were. All the treatments had some action against adult blowflies, but DDT dust was the most successful. Three treatments—DDT dust, DDT emulsion, and Gammexane dust—killed an appreciable number of adult blowflies as they emerged from the pupae.

Flies will settle to rest on outside walls if they are sunlit, particularly towards the end of the day when the wall is warm and the flies are gorged with food. All the walls near the slaughtering rooms were sprayed with a DDT wettable powder to kill these. As a result the proportion of one species of fly infesting the slaughterhouse dropped from 10% to less than 1%.

The Bookshelf

The C.I.E. International Colour System Explained. By G. J. Chamberlin. (Salisbury, The Tintometer Ltd., 1951, 34 pp., 5*s*.)

THE C.I.E. (Commission Internationale de l'Eclairage) system of colour measurement and specification has now been in existence for twenty years. It is internationally agreed and it utilises international symbols taken from mathematics and is thus independent of language. Yet it is not at all well known except to colour specialists. The authors of school texts have so far shown no knowledge of its existence.

One of the reasons for the widespread ignorance of the system in non-specialist circles is undoubtedly the paucity, indeed non-existence, of simple explanations. All the expositions have existed in books readable only at graduate level or beyond. This present book by the managing director of Tintometer Ltd., formerly a committee member of the Colour Group of the Physical Society, therefore fills an important gap in the literature.

The explanation he gives is about as simple as it can ever be, and is without talking down or distortions made to entertain without informing. It is laid out in separate small sections, each with its own sub-heading, starting from "How is Colour Seen?", going on to hue and saturation and luminance, additive and subtractive mixing, and then proceeding to the representation of a mixture of three colours by means of an equilateral triangle. The shortcomings of a practical trichromatic system are then explained, and hence the need for 'unreal' colours as primary stimuli. In this way the reader is led gently into the exposition of the C.I.E. system.

The colour illustrations are excellent, especially the frontispiece showing a colour triangle. The line drawings, all by G. D. Lovell, Tintometer's chief engineer, are very clear, and an occasional Emmett-like impishness does more in the way of exposition than thousands of words about co-ordinate geometry. Appendices explain the system of co-ordinates of a triangle and the mathematics of the C.I.E. system. This little book should do much to dispel the fog of general ignorance about the best system of colour specification ever to be invented. C. L. BOLTZ.

Cooling Towers. By J. Jackson. (London, Butterworth's Scientific Publications, pp. 104. 21*s*.)

THIS monograph is the second of the series of I.C.I. internal handbooks of design data which the Company has released for publication. It treats fully, with examples, a problem in absorption and uses it to illustrate the general approach with particular reference to the concept of the height of a transfer unit (H.T.U.). F. E. WARNER.

Lost City of the Incas. By Hiram Bingham. (London, Phoenix House, 1951, 224 pp., 21*s*.)

THE Kon-Tiki expedition from Peru to Polynesia, although devoid of any archaeological relevance, gave rise to a best-seller for which there is still a long waiting list at every public library in the country, and it also helped to put Peru on the literary map. Anything written about Peru is now sure to attract readers, who will be much interested by this book written by Hiram Bingham, who discovered the Lost City of the Incas in 1911. He revives his old memories, adds an account of the Incas drawn from Markham and other sources, and illustrates the whole with about sixty beautiful photographs, presumably the best ones out of the twelve thousand which the expedition took during the years 1911–15.

Only those who know the terrible cordilleras of Peru can fully appreciate the hardships which the explorers met before they came upon the Lost City, to which, in 1533, the Incas retired, taking with them the Daughters of the Sun, and where they remained undisturbed for forty years before they disappeared into oblivion.

The book is well produced, though Mr. Bingham's text is just a bit muddled, which is not surprising, for he was over eighty when he wrote it. But this is a thoroughly enjoyable book, and provides a pleasant evening's reading.

OLIVE HARLAND.

Film Making from Script to Screen. By Andrew Buchanan. (London, Phoenix House, 1951, 8*s*. 6*d*.)

THE scientific world is making good use of film in both research, and exposition of the progress of science and its relationship to society. There is a good deal of amateurishness, however, about the efforts scientists have made in the second direction, which is scarcely surprising since the making of films requires a special talent as well as technical knowledge. It is not enough to know how to work a camera and compose an individual frame; cinema is the art of *moving* pictures, an art which has driven ahead fast, thanks to the efforts of men like Griffiths, Grierson and his school, Pudovkin and Eisenstein.

But cinema is a craft as well as an art, and this book is well worth studying, for it is written by one of the best craftsmen the British film industry has so far seen. The first part covers "simplified film production from A to Z" and is "written to form a complete course, with technicalities reduced to a minimum". Those are the author's exact words, and they are perfectly accurate. He focuses attention on the *shooting script*, perhaps the most important single item in the whole process of making a film, and goes carefully into the details involved in writing the script, but *only* after he has exploded the all-too-prevalent idea that this is a highly technical and forbidding task. Andrew Buchanan is a skilful cutter, and the advice he gives about cutting is alone worth the price of this book.

The second half of the book deals with "the general principles of film-making applied to the planning of a number of contrasting subjects". Here he deals with the filming of such things as a village, a town, a factory, a farm and a hospital, ending with a piece about "filming your own views"—in the last-mentioned he uses as a concrete example the film he made in collaboration with Dr. D. Q. Posin called *The Atom and You* which explains the beneficial uses of atomic energy as well as the terrifying scale of atomic destruction.

This book can be read with advantage by every scientist who contemplates making a film; schoolmasters, too, with the enterprise to start a film club and teach their boys how to make a film should certainly buy a copy.

The Yellow Wagtail. By Stuart Smith: **The Redstart.** By John Buxton, (London, Collins, pp. 178, 180. 12*s*. 6*d*. each.)

MODERN ornithologists are turning increasingly to the study of the life history of a single species. The fashion was set by Mrs. Nice's exhaustive account of the American song-sparrow and by our own David Lack's admirable *Life of the Robin*. Recently we have had *Reed Warblers* by Philip Brown and Gwen Davies, and now follow two exemplary volumes in the 'New Naturalist' series of monographs, on the yellow wagtail by a research chemist and on the common redstart by a poet and don. It may be said at once that the poet is no wit less scientific in his approach than the chemist; if anything he appreciates more clearly the limitations of generalisations based on the intensive study of one small colony of a wide-ranging species. The pattern of both books is the same, with slight variations. Each essentially consists of a detailed study of the breeding behaviour and biology of a quite small population of birds (the yellow wagtails for seven years in Cheshire, the redstart for two years at Bavarian prisoner-of-war camps), coupled with some more general chapters on the history, migration, geographical distribution, food and parasites of the species. Neither of the authors would claim to have made an exhaustive study of every aspect of their bird, and no doubt in the present fragmented state of biological knowledge it would be beyond the powers of any single individual to deal expertly with all aspects, physiological, anatomical, genetical, cytological, ecological, psychological and taxonomic, of any one bird. (Parenthetically, one may ask if it is really a sign of progress that our knowledge is now so complex that one person cannot adequately survey the life of a single species as a whole.) Though Dr. Smith might be criticised for having implied a general acceptance of the views he puts forward on the genetics of the *Motacilla flava* group, and for the incompleteness in certain respects of his survey of the distribution of the yellow wagtail

in Britain, both books can be thoroughly commended, both to the expert ornithologist and to the general reader with a taste for the scientific approach to natural history. *The Yellow Wagtail* is illustrated by twenty-six fine paintings in colour by Edward Bradbury and a dozen excellent photographs taken by the author. *The Redstart* has a score of photographs (one in colour) of the high standard to be expected from Eric Hosking and John Markham, as well as four drawings by Fish-Hawk. Both books have maps and diagrams.

R. S. R. FITTER.

How Your Body Works. By Geoffrey H. Bourne. (London, Sigma Books, 1949, pp. 228, 91 figures and 16 plates, 12*s*. 6*d*.)

THIS book has been written to meet the general interest that exists in the human body, and to promote co-operation between the doctor and patient in the processes of health and sickness. It is written with an historical approach so that the basis of modern interpretations of the body's functioning can be appreciated.

There are chapters on the microscopic structure of the body, blood and its circulation, respiration, how the body moves, food and digestion, reproduction and excretion, and on the nervous system.

On the whole the writing is lucid and well suited for the layman, but there are regrettable lapses. On p. 149, for instance, we are told that "certain diseases are carried by the sex chromosomes". Nor is it clearly explained why the female alone transmits the genes involved. Another unfortunate tendency is to raise topics that are taken no further. Thus reference is made to the fact that sperm in semen exhibit mutual aid (p. 151), but none of the evidence for this conclusion is described, not even briefly. The significance of the scientific study of the body for human well-being is made clear throughout the book. More might have been done to make clear the rigorousness of the scientific method in physiology, and to expound the criteria employed.

The figures might well have been bolder in their design. Some lack adequate explanatory matter (Fig. 62), some (Figs. 65 and 82) are more likely to confuse rather than to simplify the understanding of the events they diagrammatise, whilst others (Fig. 85) are more sketchy than will enable them to assist the reader to the full. It is also a pity that the figures so rarely secure specific reference in the text.

M. H. C.

Catalogue of Geological Books

A VERY useful catalogue of books dealing with geology, mineralogy and mining has been prepared by H. K. Lewis & Co. Ltd., of Gower St., London, W.C.1., the most important scientific booksellers in London. Interested readers should write for a copy direct, mentioning DISCOVERY by name.

Catalogue of Wartime German Science Books

A CATALOGUE of German books on chemical and cognate subjects published between 1939 and 1950 is available on request from the London firm of booksellers, Lange, Maxwell & Springer Ltd. It was prepared by A. E. Cummins, Librarian of the Chemical Society, and his assistant. Many of the items in the catalogue are out of print, but second-hand copies of some are available.

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